Instruments

THE MAGAZINE OF Measurement and Control

Vol. XIII
MAR. 1940
No. 3

TAG INSTRUMENTS *for the Industrial Laboratory*

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"WE'RE on thin ice," said the President to the plant manager. "We've got to show a better profit. We can't increase prices. So that's a challenge to cut production costs."

The plant manager called his staff together and asked for suggestions. One man spoke up, "I'd like to call in . . ." The plant manager agreed. Next morning an engineer arrived—made a survey of processes where temperature, pressure, or humidity played a part. Then he went to the plant manager's office.

"As an expert on these matters," he said, "I'd say you're losing $5000 through lack of temperature control. You might as well tear up a hundred-dollar bill every Monday. But here's what you can do . . ."

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* * *

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Taylor

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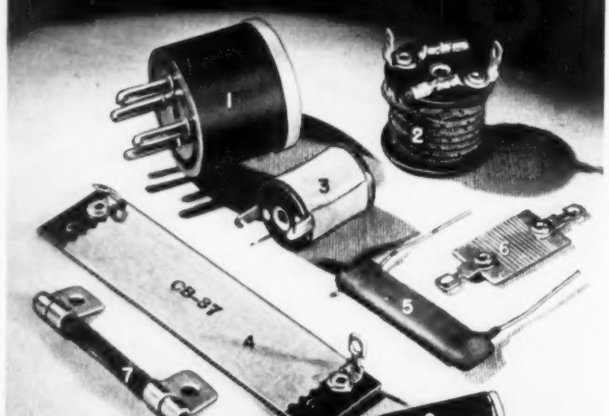

● Nine times out of ten you will find just the resistor you need listed in our loose-leaf catalog sheets. But that tenth time, when your exact requirements are not met by standard items, we are ready to collaborate in the development of that special resistor. Here, for example, are typical resistor developments for meeting unusual requirements:

1. **Plug-in precision resistor for ready interchange of resistance values.**
2. **Semi-precision bobbin-type resistor.**
3. **Another semi-precision bobbin-type resistor.**
4. **Typical precision strip resistor, made to tolerances as close as one-half of one per cent if required.**
5. **Flat non-inductive bakelite-core cement-coated low-wattage resistor.**
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7. **Fibre-glass power resistor for current-limiting applications in automobile electrical systems.**
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Uncataloged, unstocked, non-standard, these resistors nevertheless are available when and as special requirements call for them.

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Instruments

THE MAGAZINE OF MEASUREMENT and CONTROL

Vol. XIII MARCH 1940 No. 3

FRONT COVER: Microscope used as regular production tool in a welding department.
Courtesy Linde Air Products Co.

EDITORIAL COMMENT 63

NEW INSTRUMENTS 64
Indicators, recorders, controllers, inspection devices, etc., for plant, field and laboratory

FURNACE ATMOSPHERE CONTROL 73
Generation and automatized operations
By H. M. Webber

SYNCHRONISM INDICATOR 77
Cathode-ray Type
By Frederic S. Beale

PHYSICAL PROCESSES AT THE POINT WHERE HARDNESS IS TESTED 79
By S. R. Williams

MANUFACTURERS' NEW LITERATURE ..... (Insert)

ADVERTISERS' INDEX ..... (Insert)

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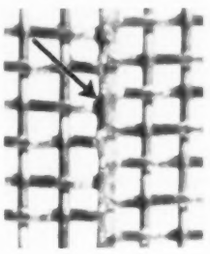
EDITORIAL COMMENT

"Laboratory" and "Plant" Instruments

By M. F. BEHAR

I—Non-stop Flight from Lab to Shop

IF you merely gave a cursory glance at the front cover photograph, please examine it, for it is only upon close scrutiny that the microscope turns out to be a binocular. Yes, the most modern type of microscope—usually considered a laboratory instrument—is shown in use as an adjunct to a brazing operation. This alone would not be important, for laboratory instruments are occasionally borrowed by production departments. What distinguishes this particular photograph is that it shows a fine modern "laboratory" microscope being used on a regular production job, in a welding department where joints are continuously made in wire screen with mesh as fine as 76 to the inch. Here is a magnified view of the type of seam produced. For this work the binocular microscope is a *necessary* adjunct. It has become a production tool. A recent visitor, shown the front-cover picture, asked if the idea was to claim that the dividing line between laboratory apparatus and industrial instruments has finally vanished. We answered no. "What then?" We found it difficult to formulate an explanation at once, but the train of thought led at last to some definite conclusions. Every industrial instrument, of course, is largely the result of research previously carried on in laboratories. Its prototype, however, may or may not have been a laboratory instrument. Moreover, laboratory instruments do not all have equal chances of becoming industrial instruments. (Of the process of "becoming," more later.) In fine, we believe that the operation shown on this month's front cover is a rare example—perhaps the first instance—of a fine, fully-developed laboratory instrument being adopted immediately and without any modification by a production crew—being taken over not merely to a *plant* (this isn't extraordinary, as will be shown) but to a *shop*.



Courtesy Linde Air Products

II—Where the Hop is Short and Significant

It frequently happens that real laboratory instruments—precision instruments of types which slowly evolved into their modern forms through generations of use in laboratories—may find immediate uses in *inspection* and *testing* departments of modern industrial plants without requiring modifications. This means, on the one hand, that laboratory instruments have become more rugged and more "foolproof" in recent years; but it also means on the other hand that the types of men and women employed in the inspection and testing departments have become more "scientific" in recent years—and this trend has been paralleled by the gradual elimination of reliance on human judgment in the inspection and testing of materials and manufactured goods.

In referring to these trends as "parallel" we do not merely mean that they are contemporary. We really mean that they go together. The minimization of reliance on human senses—in a word, "automatization"—does not imply that unskilled boys and girls can be hired as inspectors and testers who have nothing to do except to keep automatic instruments oiled and to turn off the power if something goes wrong. That's the kind of nonsense which too many orators and writers are propounding these days. The plain fact is that the humans in charge of these robots have to be well trained and are well paid.

As a matter of fact there is a field of testing of finished products which has "gone scientific" at such a rapid rate that technicians cannot be trained fast enough to fill the vacancies. We refer to the modernized performance testing of machines—and by "machines" we mean a wide range of products from household appliances to turbogenerators, internal combustion engines, road vehicles, aircraft, etc. One phase of this kind of testing was illustrated in last month's "pictorial progress report" on what the aircraft industry is doing in this line. It may not be amiss to reprint the opening statement:

"By modernized testing we mean more than soundproof rooms with observation windows, even more than remote-control systems: we mean the measurement of every factor influencing the performance of the product tested; the accurate measurement of even minor factors; the continuous measurement of every factor; the autographic recording of many data previously logged by hand; and the positive control of every known-and-controllable condition."

III—The Long Flight and Its Fascination

Although this fast-growing field of performance testing creates immediate uses for some instruments which had been developed in laboratories for laboratories, it has adopted with least difficulty those instruments, meters and auxiliary devices which have been developed to their present forms in response to the rigid requirements of purely industrial operations and processes: manufacturing, power-generation and distribution, transportation, communications, etc. And now we have come to the subject of process control. Here is where the majority of instruments differ radically from their ancestors in the laboratory. In many instances the evolution has amounted to a thorough transformation. One look at a boiler control board, for example, suggests a long way from the laboratory. The fully automatic and autographic CO_2 instrument bears little resemblance to an array of glass burettes, pipettes, etc.

To our way of thinking, one of the most instructive subjects of serious study is the evolution of laboratory apparatus into industrial process control instruments—an evolution which is going on right now at a faster pace than ever before. We can't understand why the universities and technical schools have never (to our knowledge) assigned this subject or even suggested it to aspirants and candidates for engineers' and doctors' degrees and scholarships and fellowships. We should like to be able to lead a group of engineering school sophomores in front of a heat-treating furnace control board, point out a recorder-controller of the self-balancing potentiometer type with automatic-reset or droop-corrector features and set them the task of tracing its ancestry. By the time they got through, they would not only deserve academic honors but they would be of above-average immediate usefulness to Industry.

We dare make a prediction which may sound over-enthusiastic but which we believe another ten or fifteen years will prove to be true. It is this: one of the most fascinating chapters in a "Technological History of the United States from 1920 to 1950" (yes, 1950) will bear some such title as "The Industrialization of Laboratory Instruments."

IV—Many Routes from Lab to Plant

We further predict that the future technical historian could limit such a chapter to instruments pertaining to *chemical* processes. And to demonstrate that our prediction is based on something firmer than thin air, we shall proceed to sketch out a portion of such a chapter—the portion dealing with industrial instruments for the measurement and

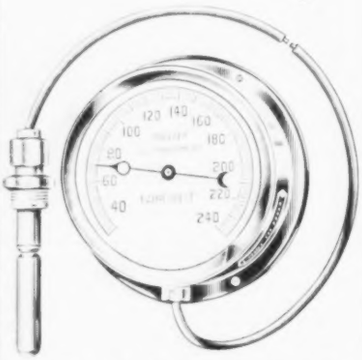
Continued on page 84

MOELLER
PRECISION GRADE INSTRUMENTS

★

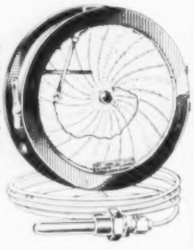
Our mercury thermometers are made with the Moeller Glass Red Reading Column which makes them easy to read under varying light conditions, at a considerable distance and over a wide range.

★



Moeller dial thermometers are made in various scale ranges up to 1000°F. or equivalent in both Metal and Phenolite cases.

Moeller recording thermometers are likewise furnished in various ranges up to 1000°F. or equivalent. Round and square cases, as preferred.



Also HYGROMETERS
RECORDING PSYCHROMETERS
BAROMETERS HYDROMETERS
MARINE INSTRUMENTS, ETC.

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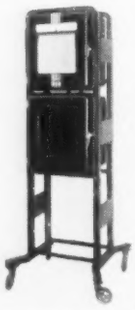
THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

High Speed Pyrometer Recorder



Completely redesigned "Speedomax" recorder draws a continuous curve of moving billet, slab, rail, etc. temperature. Showing not only temperature of the work, but also temperature gradient between its ends, chart record is reliable guide to rolling mill operations. In field of scientific research, applications include recording of: temperature, pressure and humidity measurements radioed from high altitudes; speed, radio field strength and microphotometer measurements.—*Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.*

Insulation Tester

New "Model 201 Vibrotest Insulation Testing Instrument" is a self-contained a-c.-d-c. voltmeter-ohmmeter-megohmmeter by means of which six voltage ranges and two resistance ranges are available at the turn of a selector knob. Principal applications are found in testing rotors and fields of motors, generators, etc.; also railroad signal insulation resistances. (Not intended for ground resistance measurements—for which maker's "Model 251 Vibroground" is specially designed.) Principal feature is circuit design and standardization of synchronous vibrator whereby potential of 500 volts d.c. is obtained for measuring purposes from two No. 6 dry cells. This is used when measuring megohms (on scale calibrated 0-200). Standardization is accomplished by depressing push button half-way and rotating zeroing knob until pointer is at scale zero. Ohms measurements (0.25 to 2000) are made when operating at a potential of 2.5 volts; initial adjustment being made in same manner as for megohms. D-c. voltages (scales 0/150/300/600) are read on d'Arsonval movement; a-c. voltage ranges employ rectifier.—*Associated Research, Inc., 16 N. May St., Chicago, Ill.*

Vacuum Thermocouples

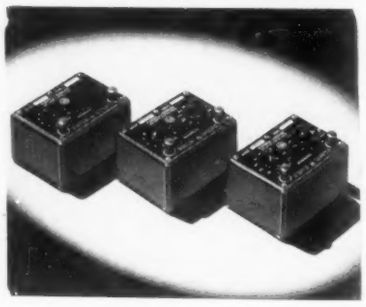
New vacuum thermocouples in a wide selection of ranges are suitable for use at practically all frequencies. Their energy consumption is said to be "low"; their sensitivity is claimed to be excellent. Current measurements may be made to a fraction of a milliampere and voltage can be measured down to about 25 millivolts. The overload characteristics of these thermocouples are said to be excellent, and are as high as vacuum thermocouple manufacture permits. Direct current may be used to calibrate these couples, reversed readings being necessary only for extreme precision. Calibration curves are available and any thermocouple can be supplied mounted in a standard UX base.—*Field Electrical Instrument Co., 2738 Jerome Ave., New York, N. Y.*

Distilled Water and Condensate Checker

New model has improved internal voltage regulator system so that instrument calibration varies less than ±2% with line voltage change from 100 to 135 volts. Conductivity cell has been provided with external metal protecting tube to eliminate possibility of damage to electrode. — *Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

Capacitor Decades

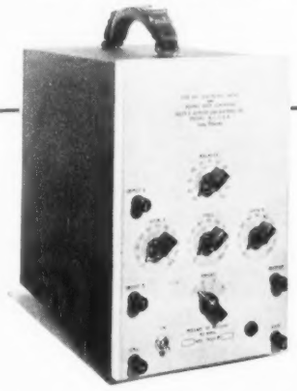
One hundred thousand different capacitance values are provided by a new series of capacitor decade boxes. The "CDA-5" box provides values of 0.0001 to 0.011 mfd.



in steps of 0.0001 mfd. or a total of 100 different capacity combinations through the medium of its two 10-position switches. "Model CDB-5" is similar except that its range is 0.01 to 1.1 mfd. "Model CDC-5" with a range of 1.0 to 10.0 mfd. has a single switch which provides steps of 1 mfd. These boxes may be used singly or in combination. The three in combination provide a range of 0.0001 to 11.1 mfd. in steps of 0.0001, or a total of 100,000 values. Each switch position is directly calibrated in mfds. and these values are accurate within ± 5% of the actual values. In addition each box is accompanied by an individual chart giving the exact values for each switch position, for use in precision work. "Model CDB-3" and "CDC-3" boxes are also announced—similar to the CDB-5 and CDC-5 models except that they provide the narrower tolerance of 3%.

All units are housed in 3⅝" × 5" × 3" walnut Bakelite cases with etched metal panels. Rated voltages are 220 a.c. and 600 d.c.—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

You need the ELECTRONIC SWITCH...



● Multiply several fold the usefulness of your cathode-ray oscillograph with the DuMont Type 185 Electronic Switch!

This handy, portable, moderate-cost instrument provides a switching-rate variable from 6 to 2000 times per second. Also operates as square-wave generator over frequency-range from 60 to 400 cycles per second. Here are typical uses:

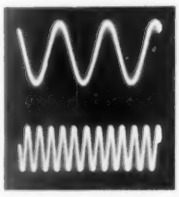
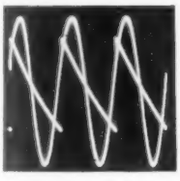


Photo showing comparison of two harmonically related signals on single oscillograph screen, using electronic switch. Patterns displaced for individual observation. Can be superimposed if preferred for very close comparison.



Independence and freedom from interaction of two channels shown in this photo. Illustrates ability of electronic switch to handle sawtooth and sinusoid at same time, and to make them appear as one oscillograph pattern.

Write for DATA...

● Literature describing DuMont Electronic Switch and DuMont Oscillographs sent on request. Do not hesitate to submit your problems for our specialized engineering collaboration.

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Rheostats With Coarse and Fine Adjustments

Maker's line of lubricated-contact rheostats (detailed description *Instruments*, Dec. 1939, page 316) has been expanded by a series of models with two windings in series—one winding of high ohmic value serving for coarse adjustment; the other with low ohmic value, having considerably fewer turns of larger diameter, accomplishing the fine adjustment over the entire regulating range. This arrangement thus divides each coarse-adjustment turn into a number of fine-adjustment turns. Ratios from 5-to-1 to 50-to-1 are available; in numerous combinations of total values of coarse- and fine-adjustment windings.—*Rex Rheostat Co., 37 West 20th St., New York City.*

Null or Deflection Method Thermoelectric Pyrometer

New "Model 70-PO" portable thermoelectric pyrometer employs a novel circuit whereby instrument may be used as a true potentiometer (null method) or as a deflection potentiometer. In latter case, its operation is as follows: When temperature at one point is to be measured, a thermocouple and lead (of the materials for which instrument has been calibrated) are connected to instrument. Operator places selector knob in position marked "potent.," and adjusts the slidewire knob (marked "balance s.w.") until galvanometer is on zero. Instrument then will indicate correct temperature regardless of lead resistance by balancing thermocouple e.m.f. Next, by turning selector knob to "Defl." and adjusting "Cal. Rh." knob until reading corresponds to reading just obtained from using as a potentiometer, instrument continues to indicate temperature without further balancing operations. To check instrument at any time, operator uses it as a potentiometer, this being said to be "a matter of but a few seconds." For installations where instrument is used with a plurality of thermocouples and where scale range is 0-400°F. or above, there is provided a selector switch including, in its housing, calibrating rheostats for adjusting all leads to uniform resistance. Available ranges extend from below 0°F. to 3000°F., in any scale range required, minimum scale range being 100°F., so that "atmospheric range" requirements can be met. Every scale is individually drawn. Accuracy guarantee is 0.5% of full-scale deflection. Instrument proper (exclusive of thermocouples and leads) weighs < 5 lbs., measures approx. 8½" × 7½" × 5". Available thermocouples, leads, etc., include all standard materials and various styles for all important applications in aircraft and automotive tests, industrial plants and laboratories, etc.—*J-B-T Instruments, Inc., 442 Chapel St., New Haven, Conn.*

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The Mark of Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

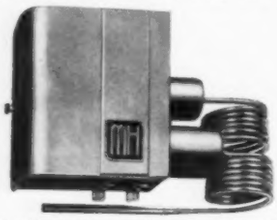
Electric Stopwatch

Differing from conventional stopwatch, new "Time-It" electric timer has a direct-reading counter mechanism driven by a synchronous motor. Principle of operation

is same as that of electric clocks; accuracy is said to be "equal to the cycle constancy of a 60-cycle a-c. supply at 110 volts." Five-digit counter reads directly to 1/10 of a second, integrates to 10,000 seconds (2 hours and 46 minutes) before running back to zero. Readings closer than 1/10 second can be interpolated and counter can be instantly reset to zero from any reading by means of a reset knob at side of housing. Stopping and starting are effected by a single "finger-tip" push button. Motor mechanism is equipped with a built-in brake to eliminate "coasting" when stopping the timing operation. "Time-It" is said to be practically noiseless in operation because the counter is direct driven by a synchronous motor. Aluminum housing with black art-metal finish; transparent plastic window. "Time-It" can also be supplied in batteries consisting of several units mounted on a single base, with single cord and plug for line connection. — *Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.*

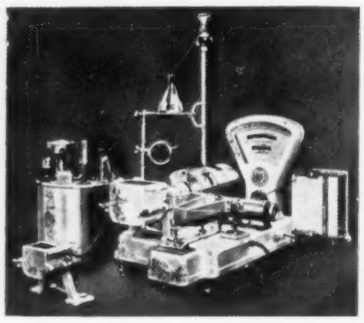
Refrigerator Controls

New light-duty "Polartrons" may be used to control refrigeration compressor motors under 1 h.p. (or larger sizes if used to pilot a magnetic-starter). They are said to



embody all features of maker's heavy-duty type "Polartron." Models are available for "low side" or both "low" and "high side" pressure control. A small pilot relay may be attached in the field, if desired, to permit room thermostat control of refrigeration. Operation is simple in that one moving lever transmits pressure changes directly into switching action. Accuracy is attainable through proper choice of lever ratios and spring rates so that slight variations in these two factors do not affect calibration. Switching mechanism is a newly-designed sealed snap-action non-magnetic switch. Separate adjusting dials (calibrated if desired) are supplied for "on" and "off" suction pressures. These dials, however, are under a separate cover to discourage unauthorized tampering. A special auxiliary "cooling control lever" is furnished with each Polartron which, when attached, will permit limited regulation of the fixture temperature by the operator. Exclusive feature, it is claimed, are separate adjustments of both the low pressure "cut-in" and "cut-out" pressures. Adjustment of one has no effect on other. These controls are said to be universal for all non-corrosive refrigerants. — *Minneapolis-Honeywell Regulator Co., 2950 So. 4th Ave., Minneapolis, Minn.*

PLASTOGRAPH



Recording Plastometer—based on the dynamometer principle and practically "weighing" the plasticity of the different materials. Measures consistency over a wide range of materials—from fairly viscous, syrupy substances to unvulcanized rubber. Has been applied successfully in RESEARCH as well as in PLANT CONTROL (for continuous operation) in the following industries:

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Can be supplied with various types of mixers or agitators—all water jacketed for efficient temperature control. Has three different sensitivity settings and can measure and record within each desired range with three times and five times increased sensitivity by the simple expedient of zero-suppression.

Pamphlet on Request

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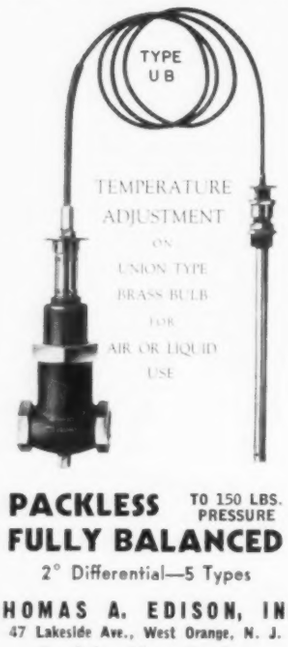
THERMOSTATIC STEAM VALVE



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FULLY BALANCED
2° Differential—5 Types

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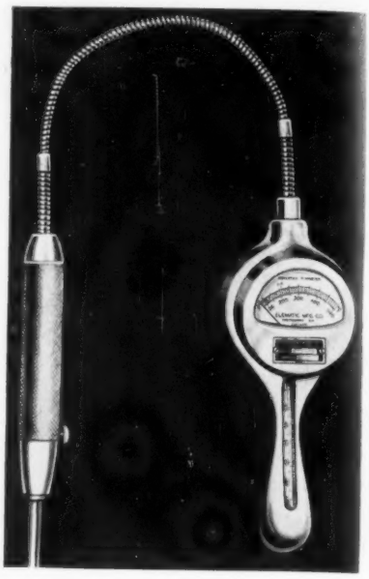
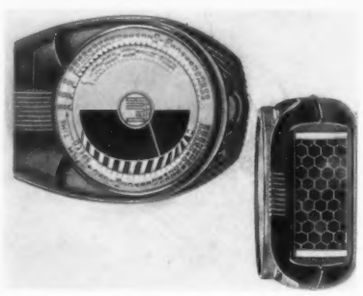
Announcement is made of a new line of portable thermoelectric pyrometers comprising several catalogued special-purpose assemblies and a number of combinations



assembled to order, whence the designation "Custom Built." Illustration shows "Model 403-10" for liquids, syrups, semi-plastics, etc. Thermocouple fixture (beyond handle—not included in illustration) is supplied in a choice of shapes, dimensions and outer-tube materials for corrosive and non-corrosive applications. Other catalogued models are for surface temperatures, air temperatures, etc. Instrument movement is high-resistance millivoltmeter with cobalt magnet, sapphire jewels, knife-edge pointer, 2⅜" scale and reference-junction temperature corrector. Compensation means comprises a mercurial thermometer conductively connected to reference junction, which arrangement is said to be an exclusive feature.—*Elematic Mfg. Co., 7542 South Chicago Ave., Chicago, Ill.*

Exposure Meter

New "Critic Model 40" photoelectric exposure meter is claimed to be "the most sensitive yet developed in the field of light reading instruments." Sensitivity is said to



range from ½ to 2000 foot-candles. Case, designed by Gorham, is one-piece plastic, sealed for protection from humidity. Film speed ratings are from 0.3 to 800; shutter speeds range from 60 seconds to 1/2000 second. Zero adjusting screw is provided. Instrument can be used equally well in either right or left hand. A louvre in front of photocell restricts angle of light acceptance to that in camera lens. — *DeJur-Amsco Corp., Shelton, Conn.*

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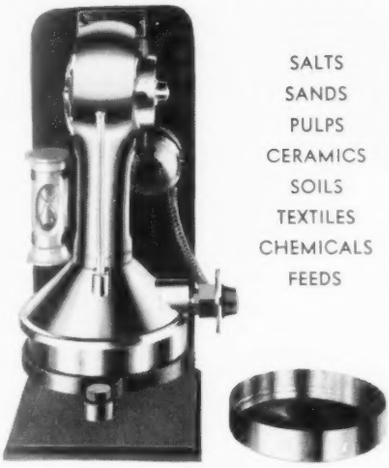
with the
Moisture Teller



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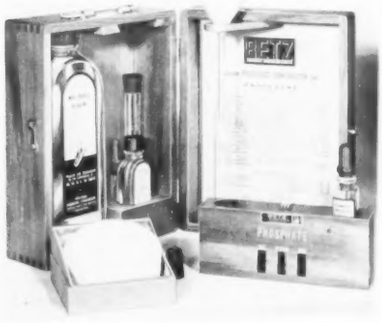
Smoke Density Indicator and Alarm

New photoelectric equipment, designated "Photoswitch Electric Eye Smoke Alarm Densometer," continuously indicates smoke density on a 4⅜" dial which reads "0" to

"100," is readily set so that a large red signal light indicates when smoke density exceeds a predetermined value consistent with efficient combustion. Equipment consists of (reading from left to right) photoelectric control, densometer-signal combination, and light source. Light source and photoelectric control are mounted on opposite sides of flue or breaching, and are aligned through simple entrance tubes or windows so that beam projected from light source strikes photocell of control. Densometer may be placed near the other furnace controls. —*Photoswitch Inc., 21 Chestnut St., Cambridge, Mass.*

Phosphate Comparator Set

For determining excess soluble phosphate in boiler water, new "Betz Junior Phosphate Comparator Set" is a simplified comparator; an adaptation of colorimetric



method of determining soluble phosphate. New set is said to have been designed especially for use in plants where time or personnel limitations make more elaborate methods impractical. Announcement lists main advantages as follows:

(1) No strong acids to handle; (2) Results obtained in 3 to 5 minutes; (3) No boiling necessary; (4) Apparatus easy to keep clean; no special solvents necessary; (5) Minimum liability to breakage. Set is regularly furnished with two standards (30 to 60 p.p.m.), permitting control of phosphate within that range. Standards of 20 and 40, or any other specified ranges, can be supplied on request. Set is complete, consisting of a wooden cabinet, removable comparator block with two permanent (maximum and minimum) color standards, two graduated mixing tubes with rubber stoppers, two graduated test tubes, one 20 cc. vial and graduated pipette, one extra graduated pipette and nipple, one 2" funnel with extra long stem, one box No. 5 Whatman filter paper, one 16-oz. bottle molybdate reagent, one 1-oz. bottle stannous chloride (concentrated), together with complete instructions. Net weight complete, 5 lbs.—*W. H. & L. D. Betz, 59 Church St., New York City.*

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Photoelectric and Capacity Relay Set for Plant Try-outs

"Rehtron Model E-77 Experimental Set" is designed for use by plant engineers and executives, research men, etc., in determining profitable applications of photoelectric

and capacitive relays. Although its cost is that of a "toy" set, certain of its components are suitable for continuous service in industry. The set as a whole may even be used in permanent installations where heavy-duty characteristics are not required. Included with each set is a 24-page instruction book written in non-technical style so that both theory and practice may be understood by laymen novices as well as engineers. Some experimental and practical applications described in instruction book are as follows: *Photoelectric relay applications*—burglar alarms, open and closed circuit; fire alarms, open and closed circuits; traffic signal control; illumination control; inspecting and sorting; machine safety control; automatic door operator; liquid level control; smoke control; magnetic counter operation. *Capacity relay applications*—liquid level or position control; pilot flame control; thermostat and humidistat control; body capacity relay operations, etc. Principal components of set are as follows: (1) "Robot Control Relay." Complete assembly of transformer, potentiometer resistor, relay, condensers, resistors and sockets in metal housing with removable base plate; size 6" × 4" × 2". No. H-7E6 amplifier tube; No. P-30 photocell (self-shielded, caesium emissive type). Designed for 110-120 volt, 50-60 cycle operation only. Consumes 5 watts. Outlet contacts deliver 6 volts, ½ ampere a.c. Selective open (forward) or closed (reverse) circuit operation. Includes special adapter for replacing photocell to transform robot into "Capacity Relay Robot." (2) Light Source Model L-50: light-proof construction with removable friction cover and adjustable-focus mounting base; size 5" × 2¾" × 2". Transformer, on cord-and-plug assembly, delivers 6 volts to #55 light bulb in adjustable socket; has rotary control switch; removable infrared filter; fixed focus lens. For 110-120 volt, 50-60 cycle operation only. Consumes 5 watts. (3) Model S-2 Signal-Switch Panel Board, ⅜" plywood size 6" × 7⅜", wired complete for audible and visible signals; selective open (forward) or closed (reverse) circuit operation, 3-conductor cord for connection to "Robot" outlet strip. Has two s-p. d-t. switches; single coil buzzer and porcelain miniature base lamp socket with #46 bulb.—*Rehtron Corp., 2159 Magnolia Ave., Chicago, Ill.*

Bin-level Indicator

A novel, positive-measurement, intermittent method of indicating level of material stored in a bin, is employed in new Dracco Automatic Bin-level Indicator. Method is essentially similar to sounding from a ship by "heaving the lead" and measuring the immersed length of the fathom line. Difference is that (after initial "sounding" when instrument is installed) cable is not rewound on drum entirely but only slightly more than necessary to take up the slack. Another difference is that all operations are automatic. A pointer on outside of bin indicates level of material in the bin. In addition, device can be tied in with an alarm bell or light to call operator's attention. System consists essentially of a reversing motor, time delay circuit, reduction gear, cable drum, and two mercoid switches. When it is put in operation, drum rotates,

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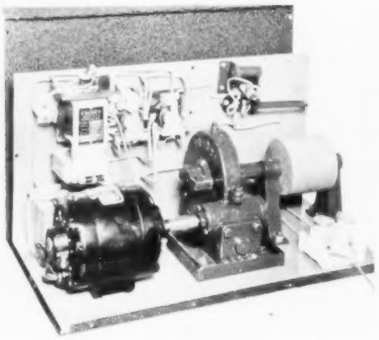

unwinding cable until weight attached to end of cable rests. This allows slack in cable which permits mercury switch to make contact that causes motor to reverse for a given period of time determined by the setting of the time delay switch. Cable is now rewound on drum and weight is raised until time delay switch cuts out. As soon as this switch breaks contact, circuit causes motor to rotate again in a forward direction until weight again strikes material. Cycle continues to repeat itself, and weight follows level of material in bin. The second Mercoid switch is mounted on top of bin, and when weight makes contact with it, this second Mercoid circuit can either start or stop motors or set off an alarm system.—*Dracco Corp., Harvard Ave. & 116th St., Cleveland, Ohio.*

White-surface Steel Tape

"Chrome Face" is name of new line of chrome-plated steel measuring tapes with black markings and white surface, "unusually free of glare." Chrome Face tapes

in cases are offered in two brands: "Anchor" in ⅜" and ½" width, in genuine leather case; and "Leader," ⅜" wide, in imitation leather case. Included also are Chrome Face ⅜" and ½" tapes on metal frames with plumb bob for tank gaging in the oil industry.—*Lufkin Rule Co., Saginaw, Mich.*

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Described in Bulletin 270 which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

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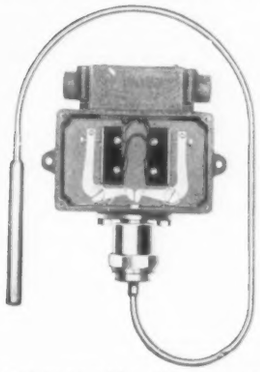
Single- or Double-switch Temperature Controllers

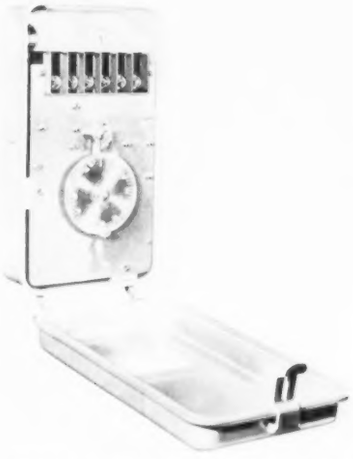
New "Model N" temperature controllers have maker's mercury-in-steel thermal systems, available in six ranges from 0-150°F. to 100-1000 F., all elements of any range



being interchangeable. Mercury expansion actuates, by means of diaphragm, either one or two Micro Switches. These are available in three types, making six combinations. Various wiring arrangements, lever and spring positions, and manual-reset feature, greatly increase the number of control possibilities. For example, announcement gives prominence to wiring diagrams showing two loads (two sets of heaters, etc.) for applications requiring precise control. Illustration shows two-switch model with cover removed. Capacity of each switch is 500 watts a.c., 50 watts d.c. In double-switch models, each is independently adjustable; one may be used for thermal element failure protection.—*The Partlow Corp., 2 Campion Road, New Hartford, N. Y.*

Automatic-reset Timers

"An almost unlimited number and variety" of industrial operations can be controlled, it is said, by means of new series of Automatic Reset Timers and Time De-



lay Relays. Among distinctly-classifiable types of uses are the following: (1) To close and then reopen a circuit; (2) To open and then reclose a circuit; (3) To make a momentary contact; (4) To repeat a preset schedule of momentary contacts or timed "on" and "off" operations; (5) To reset instantaneously after a power failure. These new timers are furnished with eight terminals. A positive mechanical lock, magnetically operated, does away with friction and magnetic clutches and prevents possibility of any disconnect due to vibration—*Paragon Electric Co., 37 West Van Buren St., Chicago, Ill.*

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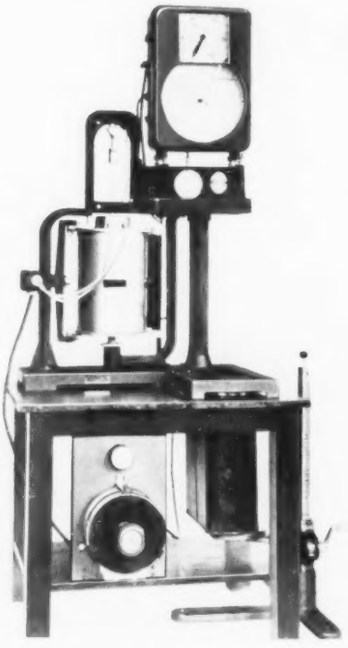
Dilatometer for Thermal Analyses of Materials

New "Model RB" Rockwell-Bristol Dilatometer indicates and records time-dilatation changes and temperature-dilatation changes simultaneously during heating and cooling cycles of materials of rigid form. Designed by Stanley P. Rockwell, it supersedes all other dilatometers made previously by the Stanley P. Rockwell Co. Temperatures are recorded by maker's "Pyromaster" recording potentiometer (see *Instruments*, April 1937, page 97; July 1937, page 172; Nov. 1937, page 277) modified only in that the 12" round chart is rotated by length change of specimen being investigated, and time element recorded by a separate pen through a Telechron clock. Heating furnace is of split type, setting vertically. Heating chamber is 3" diam. by 8" long. Furnace is rheostat controlled, operates on 110 or 220 volts a.c. or d.c. Sample is supported on quartz tubing and platform and quartz tubing to the magnifying lever system to a 4" dial, and thence to the Pyromaster. Furnace may be kept closed during cooling or opened for faster cooling, or sample and supporting system may quickly rotate 90° over a quenching tank, which in turn is quickly raised to immerse specimen in brine, water or oil. With the aid of a program controller (extra) cams may be cut to raise or hold or cool the specimen to any time cycle desired. Parts affected by furnace heat radiation do not affect any of the mentioned uses of this instrument, except that of obtaining coefficients of expansion. For this work calibration is only needed when new quartz system replaces broken quartz parts, and in making this calibration necessary data of metal expansion due to furnace radiation are eliminated. For investigations involving sub-zero temperature quenching and immersion of specimen, dilatometer needs only a change in calibration of the Pyromaster. Furnace alone, in a horizontal position, may be used as an ordinary combustion furnace, or as a thermocouple checking furnace to check shop thermocouples with their protection tubes against a standard.—*The Bristol Co., Waterbury, Conn.*



J-B-T Announces a REALLY NEW POTENTIOMETER

Panel View—Model 70-PO

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Accuracy is ½% full scale deflection, providing ½° measurement when total scale range is 100° F., even in the atmospheric range.

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On scales of 0-400° F. and higher, Model 70-PO brings this exclusive innovation: *Once balanced and adjusted, the instrument requires no further balancing operation regardless of the number of thermocouples or (within large limits) regardless of lead resistance.* Here are the advantages of the potentiometer with the convenience of a direct deflection instrument!

Thermocouple tips, detachable from the instrument, make installation easy. More important, they give readings where other temperature-sensitive elements would be too large, too slow in response, too fragile, or impossible to place. Temperatures varying at a rate such that total scale is spanned in ten seconds can be followed and measured.

Circuit design and infrequency of balancing require but one flashlight cell, which is easily replaceable.

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Invented by the same engineer to whom were entrusted the temperature measuring problems of the transoceanic planes, Model 70-PO weighs less than 5¼ lbs. Instrument comes in lustrous, durable mahogany case, 8½"x7⅝"x4-15/16" — 3-11/16" with cover off — engraved bakelite panel and leather carrying handle. Special Triplett microammeter with 6" hand-drawn scale and pointer of sturdy double-pivot galvanometer directly below; cold junction brought inside case where full compensation for ambient temperature is made.

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Type K
1/1500 hp

for precision instruments, timing devices, etc.

With and without built-in speed reducer

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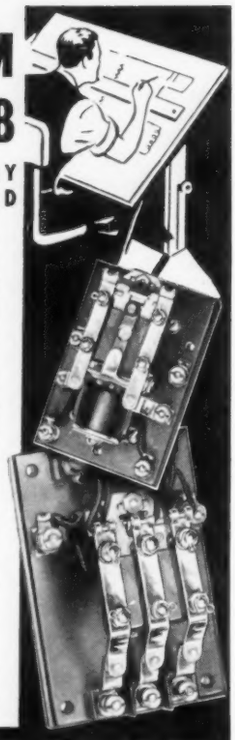

There is one right way to buy relays; that is, to make sure they are designed right in the first place, then specifically adapted to your application. This is where Dunco comes into the picture in a big way. Backed with one of the largest lines of quality relays, timers, etc., and with years of practical experience in fitting them to the specific needs of leading users, Dunco engineers are in an enviable position to help you get the most for your relay dollars in terms of dependability and long, trouble-free performance. Write for the Dunco Relay Book—free upon request.

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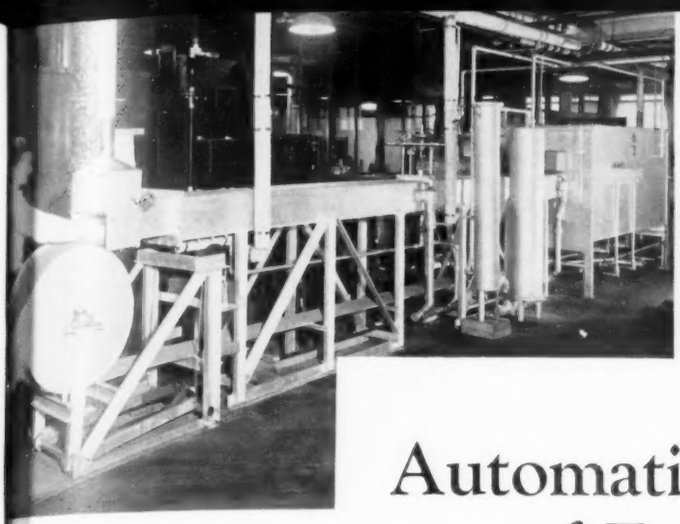
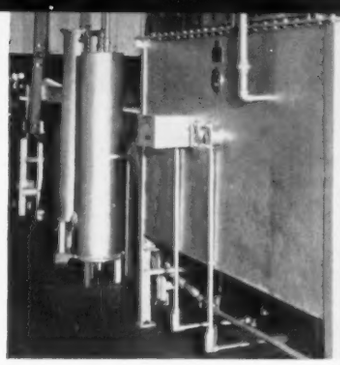




Automatic Control of Furnace Atmospheres

By H. M. WEBBER

Application Engineer, Industrial Heating Dep't
General Electric Company, Schenectady, N. Y.

Although it has been overshadowed by more recent installations, this continuous furnace makes the most suitable headpiece for Mr. Webber's article because it probably was the first of its kind completely provided with automatic control of temperature, time and atmosphere. It is the mesh-belt conveyor-type 41-kw. electric furnace supplied by G-E to RCA in 1935 for automatically brazing a vacuum-tight seal around each "eyelet" in the "headers" of all-metal radio tubes (see inset photograph). Dimly visible in the left-hand view is an atmosphere controller similar to that shown in Fig. 1 of Mr. Webber's article. The functions of other atmosphere-control auxiliaries are all explained by Mr. Webber. —MFB.

HEAT TREATMENT methods of today are to a great extent performed in furnaces provided with controlled atmospheres. These protective atmospheres are accompanied by certain advantages, such as bright, clean surfaces on products annealed; scale-free surfaces with little or no surface decarburization on hardened parts; clean, bright surfaces free from oxides and flux on furnace-brazed sub-assemblies. The furnace atmospheres employed are completely independent of the heat source and are supplied and controlled by use of auxiliaries which are generally mounted alongside the furnace. The choice of suitable furnace-atmosphere equipment and accessories depends upon the nature of the metal treated, the nature of the treatment itself, and the results which must be produced.

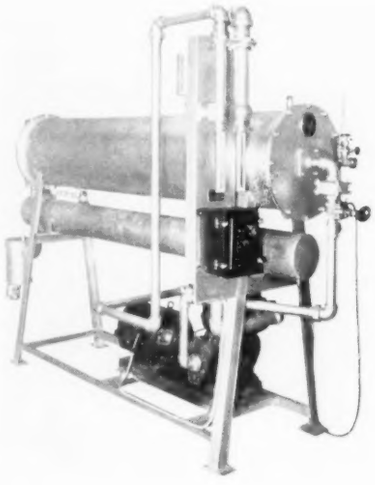


Fig. 1. Combustion-type furnace-atmosphere controller. This unit reforms hydro-carbon gases by partial combustion, converting them into suitable gases for use as atmospheres. Rating 2000 ft.^{3} hr. output.

A typical combustion-type furnace-atmosphere controller for partly burning hydrocarbon gases is illustrated in Fig. 1. A flow diagram showing its principle of operation is given in Fig. 2. This machine consists of a combustion chamber with suitable burner and fire check, visual flowmeters for measuring the rate of input of air and gas and checking their ratio, motor-operated gas-combustion controller for maintaining constant input ratio and pressure to the burner, and a surface cooler to cool the product gas to approximately the temperature of the available tap water and thus reduce the moisture content of the gas to a dew point corresponding to that temperature.

The combustion chamber contains a firing bed of suitable refractory material which has been treated with a catalyst. This aids in producing the required reaction, the result being partial dissociation and partial combustion of the fuel gas. The combustion chamber is generally water-jacketed to carry away waste heat and thus improve working conditions near the machine. The lining of the combustion chamber is designed for the service intended, it being more heavily insulated for low-ratio operation than for high-ratio operation. For low ratios, less heat is developed than when the machine operates at nearly complete combustion. A certain minimum temperature must be maintained in the combustion chamber to insure satisfactory operation. Operating on low ratios produces gases rich in hydrogen and carbon monoxide highly suitable for bright annealing, scale-free hardening and electric-furnace brazing of ferrous and some non-ferrous metals. Operation at high ratios, which develops gases containing practically zero hydrogen and carbon monoxide, is necessary for bright annealing copper if the copper includes oxygen, in order to avoid embrittlement of the copper.

Fig. 2. Flow diagram of G-E combustion-type furnace-atmosphere controller.

PREPARING THE GAS

Most controlled-atmosphere furnaces use for their protective atmospheres a gas made by the partial combustion of raw-hydrocarbon gases such as coke-oven gas, natural gas, propane, or butane. However, some furnaces use hydrogen, dissociated ammonia, raw-hydrocarbon gas, producer gas, etc., the choice of which depends upon the nature of the process, available material, and cost.

Analyses of typical gases produced by burning on low ratios and high ratios are as follows:

Constituents	Low Ratio Operation Percentage	High Ratio Operation Percentage
CO_2	4.0	10.2
O_2	0	0
CO	11.0	0.7
H_2	17.0	0.7
CH_4	2.0	0
N_2	66.0	88.4
	100.0	100.0

Raw gas enters (Fig. 2) through flowmeter *B* and is then drawn into mixer *D* on the gas-combustion controller. Likewise, air is drawn from the room through a filter *A* and flowmeter *C* to the mixer. The mixer is an accurate sleeve valve consisting of a sleeve and a piston, each with two square orifices, one for gas and one for air. The piston can be rotated manually to adjust the gas-air ratio, and it moves vertically for changes in mixture volume. Vertical movement during operation takes place automatically to meet demand. The gas enters the mixer through a governor which regulates the pressure at which it is introduced, and this pressure is always the same as the prevailing air pressure. Automatic equalization of these pressures, automatic piston adjustment, and close-tolerance machining of the square ports assure accurate volumetric and ratio control.

From the mixer the gas and air go through a positive-displacement type compressor *E* equipped with an automatic pressure regulator which maintains constant outlet pressure. From here the mixture travels successively to a lighting torch *F*, volume-control valve *G*, fire check *H*, and burner *J*.

As the reformed mixture leaves the combustion chamber it goes to valve *L* which opens to the room and which is used only during the first few minutes while starting up. This valve is normally closed and the gases are diverted through a straight-tube surface cooler *M*. In this unit is a removable bundle of brass tubes arranged so that the gas flows through one-half of the tubes and then returns through the other half. Also there are baffles at intervals to make the water flow across the tubes rather than to run along them. Thus the unit is efficient and accessible for cleaning. From the surface cooler the gases pass through a water separator *N* and are then ready to be delivered to the furnace or to accessories for further treating the gases before being delivered to the furnace. Moisture condensate from the surface cooler and water separator leaves the latter through drip trap *P* feeding into a drain. Cooling water for the surface cooler and combustion chamber passes in series through both, for the sake of economy, and is discharged to a drain.

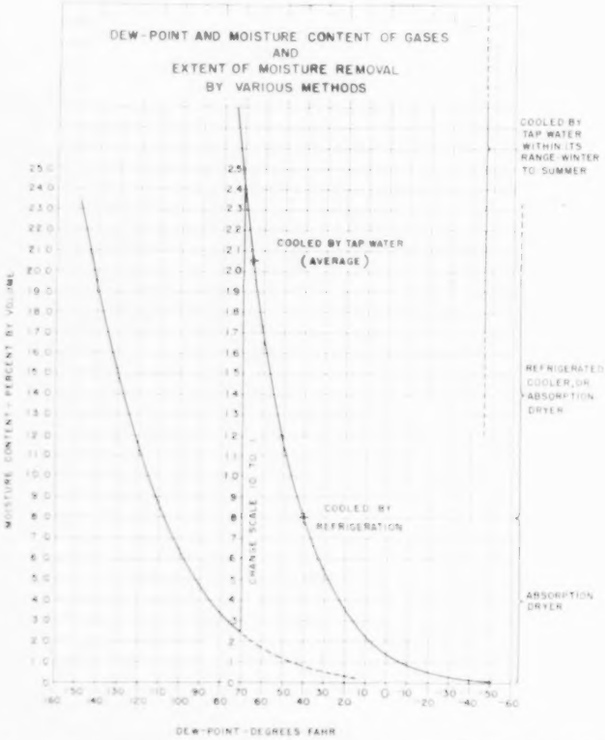

DEW-POINT AND MOISTURE CONTENT OF GASES
AND
EXTENT OF MOISTURE REMOVAL
BY VARIOUS METHODS
COOLED BY TAP WATER WITHIN ITS RANGE WINTER TO SUMMER
COOLED BY TAP WATER (AVERAGE)
REFRIGERATED COOLER, OR ABSORPTION DRYER
COOLED BY REFRIGERATION
ABSORPTION DRYER
MOISTURE CONTENT - PERCENT BY VOLUME
CHANGE SCALE TO TO
DEW-POINT - DEGREES FAHR

Fig. 3. Moisture content of gas at various temperatures. Cooling by refrigeration removes almost two-thirds of the moisture contained in the gas delivered from the furnace-atmosphere controller at approximately tap-water temperature. The moisture can be reduced to zero by means of an absorption dryer.

MOISTURE REMOVAL

As previously stated, the gases leave the surface cooler of the furnace-atmosphere controller saturated at approximately tap-water temperature. This is generally satisfactory, but for some processes the moisture content must be reduced or completely eliminated. Fig. 3 gives an idea of the further moisture reduction possible by cooling with a refrigerator and by complete removal with an adsorber such as an activated-alumina dryer. Although either of these devices is suitable for partial removal of moisture, the refrigerating equipment is generally used if the dew point does not need to be reduced below 40°F. For complete removal, the activated-alumina dryer is commonly employed, although in some cases it is economical to first refrigerate the gas, then dry it.

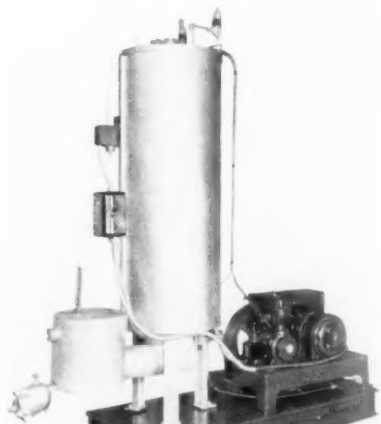


Fig. 4. G-E refrigerated-gas cooler for reducing dew point of processed gases to about 40°F. It consists of a condensing unit and liquid cooling tank. Rating 2000 ft.³/hr.

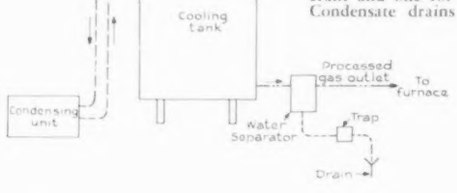


Fig. 5. Arrangement of cooler, showing connections to the two coils in the cooling tank, one for the refrigerant and one for the processed gas. Condensate drains from the trap.

REFRIGERATED-GAS COOLER

Figs. 4 and 5 show a photograph and schematic diagram, respectively, of a typical refrigerating unit. The equipment consists of a condensing unit and an insulated cooling tank filled with a solution of water and alcohol. In this tank are two coils, one for the refrigerant from the condensing unit and the other for the gas to be cooled. Thus the refrigerant cools the bath and the bath in turn cools the gas. The temperature of the bath is thermostatically controlled. The gas leaves the cooling tank at the bottom and passes through a water separator, from which it is delivered to the furnace. Condensate from the cooling tank and separator leaves through a drip trap in the bottom of the latter.

ACTIVATED ALUMINA DRYER

A diagram of an activated-alumina dryer is shown in Fig. 6. It consists of two electrically-heated chambers filled with activated alumina, with suitable valving arrangement so that gases to be dried pass through one chamber only, while the other chamber previously used is being reactivated by means of thermostatically-controlled electric heat which

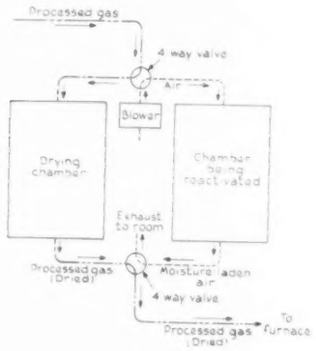


Fig. 6. Arrangement of activated-aluminum dryer, showing travel of processed gas through one of the chambers, while air is being blown through other chamber during heating and cooling period to help remove moisture collected in previous operating cycle.

drives off the moisture. A blower is used to help remove the water vapor, and water cooling coils are installed in the large sizes to hasten the cooling of the activated alumina after the mass has been dried by heat. These units are generally built so that a switch-over from one to the other is required about every eight hours.

DEW-POINT POTENTIOMETER

For checking the moisture content of gases before they enter the furnace, a dew-point potentiometer such as that shown in Fig. 7 is frequently used. A small stream of gas is conducted through a compartment in the instrument where it comes into contact with a thin metallic mirror to which a thermocouple is attached. This thermocouple is connected to a potentiometer and to an indicator the scale of which is calibrated in degrees of temperature. A window is provided in the compartment so that an observer can see the mirror, and a lamp is provided for the instrument to be used in dark places or at night. Arrangement is made for cooling the mirror by directing, by means of a suitable nozzle, a small stream of cooling gas against its back. Carbon dioxide from bottles is commonly used for this cooling gas.

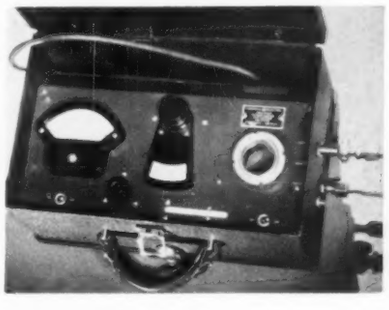


Fig. 7. G-E dew-point potentiometer, for determining the moisture content of gases. Mirror is observed through window at right.

In taking a measurement, the operator increases the flow of cooling gas against the mirror until a spot of moisture condenses on its surface. Slight adjustment of the cooling effect will then cause the alternate evaporation and condensation of moisture on the mirror. At that point the dew-point temperature can be read directly on the indicator after balancing the galvanometer by turning a knob.

SULPHUR REMOVAL

Where raw gases, such as coke-oven gas containing sulphur, are processed for use as controlled atmospheres for bright annealing copper, it is necessary that this sulphur be removed in order to avoid discoloration of the copper. Sulphur-purification equipment has been developed for this purpose. A typical equipment consists (Fig. 8) of a water-spray tower and an iron-oxide tower connected in series. The water-spray tower consists essentially of a steel cylinder filled with refractory rings. The water first passes through a visual flowmeter which indicates the rate of water consumption, then it sprays from the top down over the

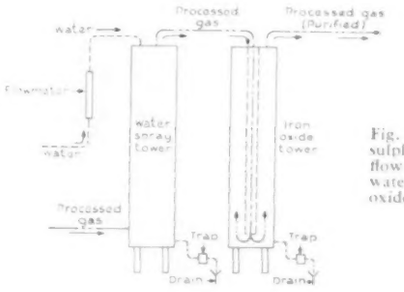


Fig. 8. Layout of typical sulphur purifiers, tracing the flow of gases through the water-spray tower and iron-oxide tower.

rings, and is emptied from the bottom by a float trap with full-opening valve. The gases to be purified enter the chamber at the bottom, rise in contact with the down-pouring water and leave at the top. The iron-oxide tower consists of a steel cylinder filled with wood shavings which are coated with iron oxide. Gas enters at the bottom of the chamber and leaves from the top. A condensate trap is installed in the bottom for draining any moisture which might accumulate.

CARBON-DIOXIDE REMOVAL

Certain heat-treating processes require reduction of the carbon-dioxide content or complete elimination of it, along with removal of moisture, in order to minimize or prevent surface decarburization of the steel being treated. Carbon dioxide can be removed in a number of ways. Fig. 9 is a

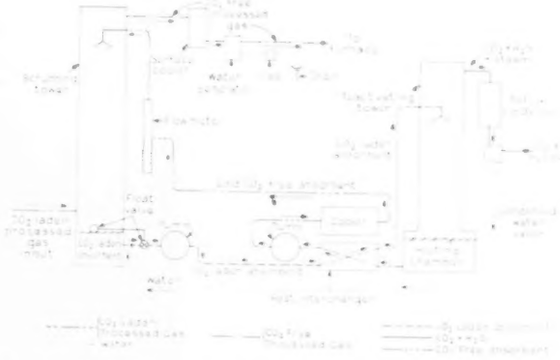


Fig. 9. Arrangement of typical sulphur-purifying equipment. Processed gases flow through spray tower at left only. Absorbent which picks up CO_2 from gases is pumped into regenerative tower at right, where CO_2 is driven off by means of electric heat. Absorbent is then cooled and recirculated through spray tower.

diagram of typical equipment for this purpose. Removal is accomplished by the use of a liquid absorber which dissolves CO_2 and holds it in solution. Upon subsequent heating, the CO_2 is driven off. The liquid is cooled and is again ready for use, thus making the process continuous and regenerative.

The equipment consists of two towers, one for absorbing the CO_2 and the other for driving it off, the liquid being continuously circulated between the towers by means of a pump. The CO_2 may be removed completely or with only traces remaining.

Another way to produce low CO_2 directly in the furnace-atmosphere controller is to add a preheater to the combustion chamber, which will permit burning on lower ratios than normal, resulting in less CO_2 being formed during the reactions in the combustion chamber. This is not practical for completely eliminating CO_2, but helps in reducing it.

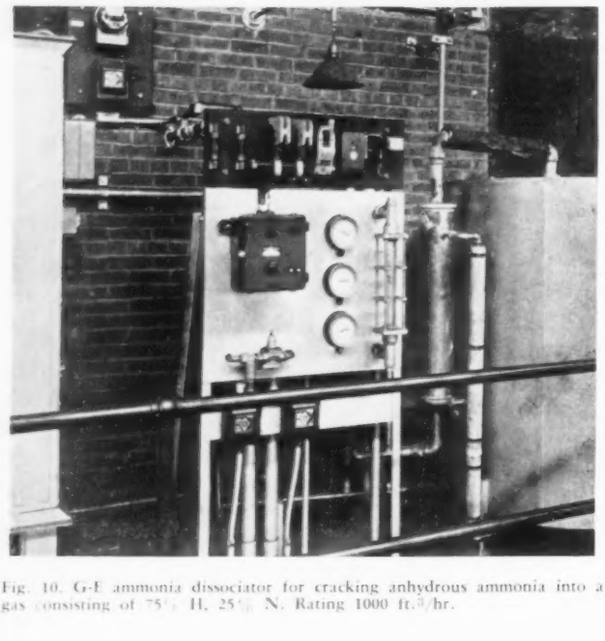


Fig. 10. G-E ammonia dissociator for cracking anhydrous ammonia into a gas consisting of 75% H, 25% N. Rating 1000 ft.^{3}/hr.

VOLUME AND PRESSURE CONTROL

For some types of furnaces, particularly those with liquid or sand seals, it is necessary to supply the gas at low pressures—say 2" to 6" water. Generally the gas is delivered from the furnace-atmosphere controller or accessories at higher pressures than this and there is installed in the line to the furnace a pressure regulator to reduce and control the pressure.

In many installations multiple retorts are employed and the load on the furnace-atmosphere controller varies from time to time because retorts are continually being cut in and out of the system. Since it is necessary to maintain a minimum flow of gas from the furnace-atmosphere controller in order to produce enough heat of combustion to keep the combustion chamber at or above the minimum operating temperature, it frequently is necessary to install a relief valve in the output line in addition to the regulator. Then if the load is reduced to a certain point, the back pressure builds up to the extent that the relief valve opens and discharges processed gas to the outdoors in sufficient volume to maintain the required combustion-chamber temperature.

AMMONIA DISSOCIATOR

A source of gas relatively free from impurities is that produced by an ammonia dissociator which cracks anhydrous ammonia into its constituents, hydrogen and nitrogen, there being 75% of the former and 25% of the latter in the output mixture. The gas contains only traces of moisture and ammonia. If the requirements are such that even these traces must be removed, they can easily be taken out with an activated-alumina dryer.

Fig. 10 shows a typical ammonia dissociator rated 1000 ft.^{3}/hr., complete with its accessories. Fig. 11 shows the flow diagram for the dissociator with its accessories. Ammonia passes from a cylinder through an expansion valve and heat exchanger into the dissociating element, which consists of a coil of alloy tubing filled with catalyst. Upon leaving the dissociator, the gas goes through the heat exchanger, a flowmeter, and pressure-reducing valve, then to the furnace. The dissociator is electrically heated, with ribbon resistors mounted on the side walls. The temperature is automatically controlled, of course, with a pyrometric system. An auxiliary panel is provided to mount the flowmeter, pressure gages, temperature control instrument, etc.

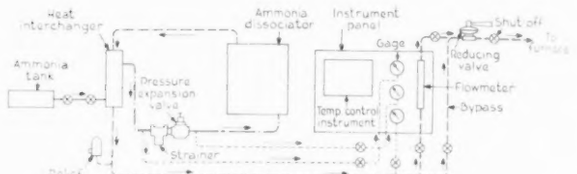
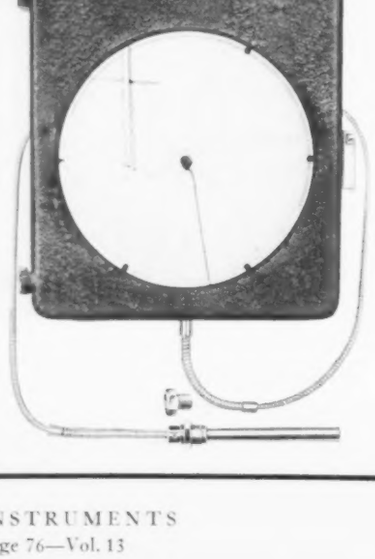


Fig. 11. Arrangement of ammonia dissociator, showing liquid ammonia drawn from the tank, vaporized, then passed through an alloy coil in an electric furnace where the vapors are cracked. Dissociated ammonia output passes through a sight flowmeter on instrument panel, then to furnace.

CONCLUSION

It is evident from the foregoing that control equipment plays a prominent part in providing protective atmospheres for furnace applications. By means of this automatic control, uniform results are assured and duplication of results is made easy. With a wide variety of equipment and accessories available, controlled atmosphere furnaces are now able to accomplish jobs which only a few years ago were considered difficult or impossible to do economically.



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Cathode-ray Type Synchronism Indicator

By FREDERIC S. BEALE
Box 2661, Boise, Idaho

THERE arose the problem of how to synchronize a 132-kv. line to a bus without purchasing a potential transformer. Our old neon-tube "Statoscope" did not require potential transformers, but such a device does not give adequate indications. The situation called for an inexpensive device providing an accurate indication; readily understandable and readable by any operator; reliable; installed and maintained at minimal cost; and requiring little attention.

An extremely simple solution was found in the application of a cathode-ray indicator tube. Some thought and experiment revealed that perhaps the best of the many such tubes available was the Type 6E5, termed the "Magic Eye" tube. At first thought it may be considered that the luminous indication on the screen of this tube would be too small to be of any use. Its very smallness is an advantage in that it enables its installation to be made at the switch control in the best position for observation by the operator. And the indication given is in brilliant green light easily seen in daylight surroundings. Addition of other tubes, in parallel, at switch controls widely separated, immediately suggested itself as being practical.

The source of operating potential, as far as the synchronizing indications are concerned, is required to supply an insignificant amount of power, and a wide latitude of source voltages is easily accommodated without any change in the equipment, other than minor adjustments of two controls which are provided. Static wires or collectors, and coupling capacitors of small capacity, become suitable sources.

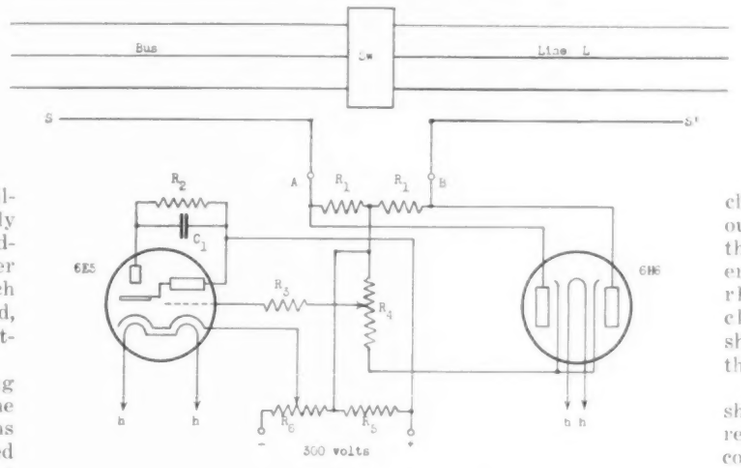


Fig. 1. Circuit diagram for synchronizing instrument. Usual circuit values are as follows:
R_1—two 500,000-ohm 1-watt resistors
R_2—1 megohm, 1 watt
R_3—100,000 ohms, 1 watt
R_4—100,000-ohm volume control (linear characteristic)
R_5—15,000 ohms, 10 watts
R_6—3,000-ohm volume control (linear, wire wound)
C_1—0.1-mfd 400-volt paper capacitor

THE CIRCUIT

(a) Fundamental: In Fig. 1 is shown the circuit that may be adapted to a wide variety of circumstances. The line, *L*, is to be synchronized to the bus by means of the switch, *Sw*. To a phase conductor of the line a short static collector wire is electrostatically coupled. Another static collector wire is similarly coupled to the corresponding phase conductor of the bus. These two static wires are then connected to the terminals of the indicator instrument, *A* and *B*, as shown.

It will be recognized that the potentials developed in each of the static wires, *S* and *S'*, will be proportional to, and of the same frequency as, the potentials of the bus and line to which they are coupled. With the switch *Sw* open any difference in frequency and resulting difference in potential between the bus and line potentials will also show a corresponding difference in frequency and a proportional difference in potential between the potentials of the two static wires. (In the case of loop circuits it may be noted here that a phase angle existing across *Sw* when it is opening the loop will also cause a difference of potentials between the static wires, but one of a constant value giving a fixed and motionless indication, in marked contrast to the ordinarily continuously changing indication found for out-of-step conditions.)

This difference of potential due to out-of-step conditions is, of course, zero at the instant of synchronism; therefore the adjustment of R_6 is made such that the 6E5 tube shows a green light pattern with only a thin black shadow pointing upward, with terminals *A* and *B* short-circuited. (Or with the switch closed; or with both static wires disconnected.) This adjustment shows the indication that will be found on the 6E5 tube screen at the instant of synchronism between the line and bus.

The next adjustment requires the actual use of the out-of-step condition across the opened switch. With static wires connected, the short-circuit removed from terminals *A* and *B*, and *Sw* opened, R_4 is set at about half scale. The thin line of shadow will come to life, and, fan-like, will spread out until it covers approximately a 90° sector, then close up to the line. The out-of-step condition is thus presented to the operator as a more or less rhythmic opening and closing motion of the shadow on the screen of the 6E5 tube.

If the motion of the shadow is to faithfully represent the out-of-step condition, the amount of voltage selected and applied to the grid of the 6E5 tube should be just that amount necessary to produce a 90° sector of shadow at the 180° out-of-step condition. This amount is most easily found by adjusting R_4 during the application of the out-of-step voltage to the instrument, and will be found when the motion of the shadow is seen to be rhythmic. If this adjustment applies too much voltage to the grid, the shadow will be found to open and close more rapidly than it should, and to remain open or closed for short periods of time when it actually should be moving. Incidentally, it is best to have an out-of-step condition of about one cycle per second for making this adjustment. A shadow having too slow a motion will be difficult to judge because changes of system speed as well as the speed of the incoming circuit have a more pronounced effect. By coördination of the two adjustments, R_4 and R_6, a setting is quickly reached that gives the maximum shadow opening, and at the same time makes it perfectly rhythmic as the out-of-step condition that causes it.

If R_4 is adjusted so that for a 180° out-of-step condition the *IR* drop selected is just sufficient to expand the shadow to its maximum, 90°, and the in-step indication is adjusted to be a vanishingly thin line of shadow, the angular opening of this shadow, expressed in degrees, will always be equal to one-half the angular displacement between the out-of-step voltages, also expressed in degrees.

(b) Permanent Installation: The power necessary for operation of the instrument is moderate and may be obtained from one of several sources. Tube manufacturers'

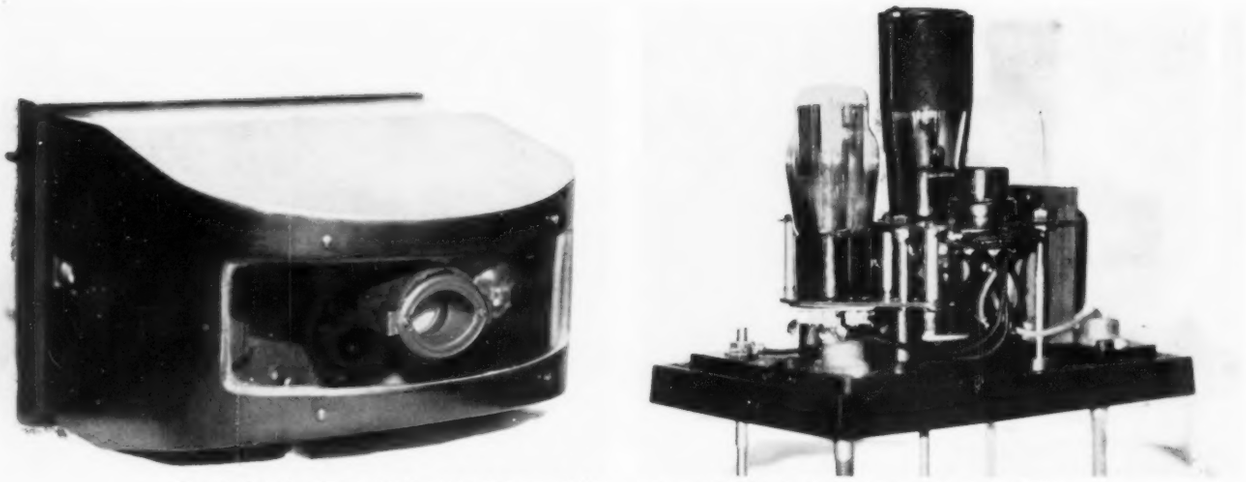


Fig. 2. Outside view and "chassis" of first cathode-ray type synchronism indicating instrument to be permanently installed on an operating company's switchboard. (It was preceded by various experimental models.) Three instruments of the type shown are now in service. Application for a U. S. patent has been filed.

specifications are followed in selecting the power supply. One is of radio receiver type, consisting of transformer for heater and plate voltages, rectifier tube and filter condenser. A six-volt storage battery and a vibrator type high-voltage supply, or a set of dry batteries, may be used instead.

(c) Portable Use: The battery type of power supply above-mentioned suggests the use of the instrument as a portable device. The patrol or service car battery could then be used to furnish power if the car could be brought sufficiently close to the scene of operations. Otherwise the full dry battery supply would be used.

(d) Extension or Remote Indications: If the control switches are in separated locations such that one indicator tube cannot be located to be viewed easily from all positions, as many extension indicator 6E5 tubes as are desired may be connected in parallel with the one located at the main instrument. They will operate from the same power supply as long as it can supply the cathode heater load. The plate power required is not ordinarily a limiting factor.

(e) Direction of Rotation: The type of indication given by this instrument does not in itself give any indication as to whether the incoming line or machine has a frequency that is higher or lower than that of the bus to which it is proposed to connect it—whether the incoming line or machine is "fast" or "slow."

Where the question is one of such importance that it is considered necessary to know beyond any doubt, an arrangement has been worked out that satisfactorily shows this information. It involves the addition of an amplifier tube to provide the power needed to operate the rotation indicator device.

SOURCES OF INDICATING POTENTIAL

(a) Insulator Disk Hardware: The old Statoscope arrangement secured potential by connecting to the insulator disk hardware. This method of securing potential can be used with the instrument described in this article, but it has not been found as satisfactory as either of the following two methods, probably due to variations in insulator disk electrical characteristics because of age, mechanical stress, atmospheric conditions, and dirt on the surfaces of the disks.

(b) Static Wires: Far more satisfaction has been had with static wires as sources of indicating potential. The installation of the wires should offer no particular difficulty mechanically. They should be installed in such a way as to be practically parallel to the phase conductors to which coupling is desired. In spacing from those conductors, a distance equal to, or somewhat less than, the conductor spacing used between transmission line conductors for the operating potential of the line in question is satisfactory.

The exact voltage produced under load at the instrument terminals is not significant; it is important, however, that where more than one line is to be synchronized to a common bus, the static wires for all incoming lines must produce the same voltage at the instrument terminals as does the bus static wire, under normal load conditions as represented by the actual load of the instrument. For this reason all wires to be installed can be put up and a set of rough voltage measurements made, from which it can be determined which wires to shorten, lengthen, or leave. The trimming process is not difficult, and is not critical as to length of wire. The spacing of the wire from the phase conductor, on the other hand, affects the voltage markedly. It is sometimes quicker and simpler to produce a small change in voltage by slacking off, or tightening up, on the wire if circumstances will permit it to be done.

(c) Coupling Capacitors: Coupling capacitors such as are now installed in oil switch bushings, or for carrier current connections, may be used.

(d) Transformers: Potential transformers, of course, can be used, but the object of this instrument was to obviate an expense that was not deemed economic.

(e) Combinations: For combinations of different types of potential sources the phase angles introduced by the source, and by the circuit connections, must be checked. Were the instrument to be used with static wire potential, phase-to-ground, from one circuit, and with synchronizing potential, phase-to-phase, for the other circuit taken from a metering equipment potential transformer, it is recognized immediately that a phase-shifting network would have to be installed to correct the two phase-angles such dissimilar sources involve.

INDICATIONS

In the use of the instrument the out-of-step indications are shown, as already described, by a shadow opening and closing fan-like within the range of the 90° sector.

Should the instrument be put in use and the operator observe that the shadow remains stationary, granting that there are no mechanical or electrical failures in the control and electrical equipment and circuits, two conditions will be indicated:

1. Where the line is part of a looped circuit, a phase angle will be indicated. Usually such angles are relatively small and depend partly upon the load carried by the lines making up the looped circuit. In this case the shadow will not show a sector width of more than half the number of degrees of phase shift that exists.

2. Regardless of whether or not the line is part of a looped circuit, if the shadow shows a sector approximating 45° width it indicates that one of the two circuits to which the instrument is connected is dead. (A third condition is possible: that of synchronism existing by chance at the time the indicator is put in operation. This, of course, would not last long when generating units are separated entirely from other parts of the system.)

Physical Processes Which Occur at the Point Where a Hardness Test is Made

Continued from February Issue

By S. R. WILLIAMS
Professor of Physics, Amherst College

Herbert's Pendulum Hardness Tester Indentations

These have already been shown to some extent in Figs. 195 and 197 (Sept. 1939 instalment). Fig. 233, however, shows in greater detail what is happening immediately under the indenting tool. The photographs in Figs. 233 and 234 were sent to the author in 1934 by the late E. G. Herbert of England. Fig. 233 is an imprint made in a bronze plate. It shows quite clearly the parallel slip bands crossing the smaller crystals of which the plate is made. Each crystal has the direction of the slip planes different from those of the others,

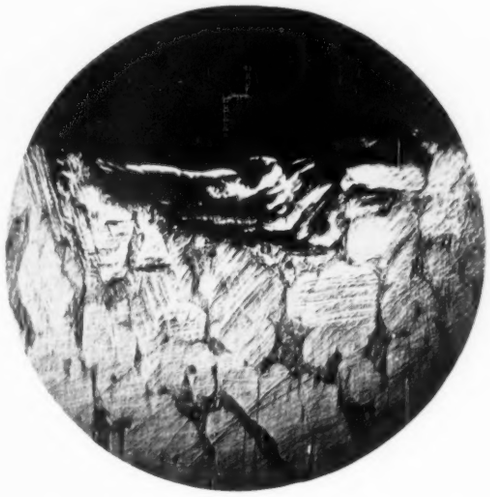


Fig. 233. Half of the imprint of the ball of a Herbert Pendulum Hardness Tester.

being a random distribution of direction of crystal planes. The slip lines are, of course, the edges of the slip planes on which slip has occurred under the pressure imparted to the material through the 1-mm. steel ball on which the 2-kg. mass of the pendulum hardness tester rests. This photograph was obtained in the same way as were Figs. 222, 223 and 225. It is a vertical cross-section of a time hardness test on bronze. Fig. 234 is a photograph of a work-hardening test impression made on the polished surface of a block of mild steel. This shows clearly the slip lines within the distinct small crystals surrounding the indentation of the ball. In a polycrystalline structure as in Fig. 227 these individual slip lines are not distinct due to the fineness of the structure and give simply a matt-surface appearance.

Herbert made many tests similar to those shown in Figs. 233 and 234 and always obtained these outstanding characteristics that slip lines could be seen in the crystal structure around and under the steel ball indenter of his pendulum hardness tester. These numerous and confirming observations led Herbert to two generalizations:

(1) "The deformation caused by hardness tests always results in deformation of individual crystals below and around the test impression, this deformation consisting of slip or gliding of crystal planes over one another."

(2) "Hardness is a measure of resistance to slip."

In order to make this last point clearer, Herbert constructed a model as follows: a heap or pack of safety razor blades was placed on an electromagnet. The pack of blades could be easily deformed by sliding the blades over each other when unmagnetized, but when the electromagnet was excited or the magnetizing force normal to the slip planes was increased the frictional resistance

Courtesy of the late E. G. Herbert

Fig. 234. Photograph of the imprint of the ball in a work hardening test. Slip planes may be seen surrounding imprint.

to slip (and therefore to deformation) was increased. *The pack of blades became harder as the blades settled together under the magnetic force.* The force required to break the pack in two by separating the blades was of a much higher order than the force to deform it by slip. In metals the crystal planes are held together by cohesion, which is so great that separation seldom if ever occurs, though slip is the common characteristic of all kinds of deformations. This point will be discussed at greater lengths when the phenomenon of creep is related to hardness.

From results (to be presented later) concerning hardness and magnetic properties, it would appear that the forces acting on these slip planes to keep them from separating were electromagnetic in their character. Whatever these cohesive forces are, heat and magnetic fields both produce a change in these forces.

Sclerometer Indentations

The physical processes involved in the mark or cut (indentation) made by the various sclerometers, or by the so-called scratch hardness testers, is of considerable interest to the users of these instruments. Fig. 235 shows a cut made in the surface of a piece of plate glass as it should be made by Bierbaum's standard instrument. This

cut was made when the diamond was carrying a load of 3 grams. When, however, the same diamond was loaded with 9 grams and moved across the same plate of glass, the scratch in Fig. 236 resulted. This is an unusual photograph in that it shows parts adjacent to the scratch completely sheared off. They could be seen with the naked eye lying at some distance from the furrow. Near the middle of the picture is one piece almost completely flaked off, while near the bottom the process has just started. Fig. 236 illustrates exactly what happens with a sclerometer in which the load is used as the criterion of hardness. The cut will not be due to a plastic flow or the slipping of one plane over the other, but a gouging and ploughing process which cannot be accurately gaged for width.

A real scratch is the one shown in Fig. 237, which is the mark made by a diamond glass cutter when one wishes to cut off a piece of plate glass. The center of the furrow is a maze of fine cracks which by diffuse reflection give a white appearance. It will also be seen that extensive flakes of the glass have been sheared off as the Indian does the flint when forming his arrow head. Some excellent photographs of the cuts made in various metals by Bierbaum's Standard Instrument are shown in Figs. 71, 72, 73 and 74. (Dec. 1937 instalment).

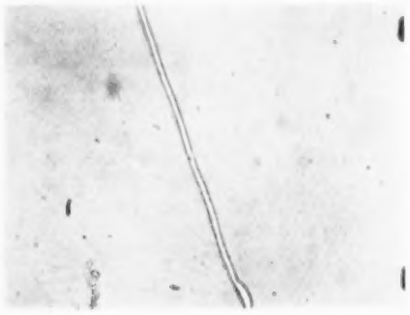


Fig. 235. Cut made by diamond on a Bierbaum Standard Instrument with a load of 3 grams.

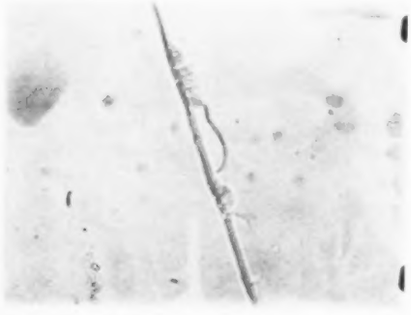


Fig. 236 Cut or scratch made by the diamond on a Bierbaum Standard Instrument when the load is 9 grams.

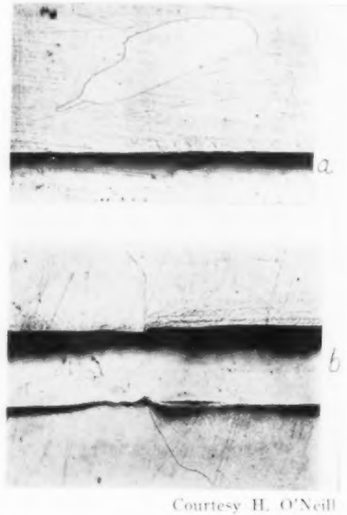
Fig. 237. The scratch made by a diamond-pointed glass cutter.

In Fig. 238 are shown the paths made by the O'Neill Ball Sklerometer as the ball crosses (a) the surface of a block of large crystals of iron and (b) when the ball crossed the boundary between two strained iron crystals. In both cases the slip lines along the edges of the groove made by the 1-mm. ball may be plainly seen. This type of point for the stylus is recommended by O'Neill because he believes that he can maintain a more uniform point on a ball-ended stylus than on a diamond ground to a sharp point. The latter is too easily shattered or damaged in the process of making a cut. O'Neill reports that "the ball sklerometer gives excellent results on single crystals of metal and satisfactory tests on aggregates." One well-known maker of concave gratings tells me that after ruling 50 inches of speculum metal, averaging 30,000 lines to the inch, and with each cut about one inch long, he has not been able to detect under high magnification any change in his diamond point. If there were it would spoil the resolution of the grating.

In Figs. 183 and 184 (Dec. 1938 instalment) the imprint of the Shore scleroscope was compared with that of the Rockwell indentation. They are quite different in their character.

Various Imprints in Glass

The imprints of the Auerbach spherical indenter on the surface of a plate of glass were shown in Fig. 88 (March 1938 instalment) at the moment the first permanent crack (deformation) appears in the glass. It is of interest to compare the impact hardness testers' imprint, Fig. 239, with the static imprints given in Fig. 88. The striking thing about them is that both in the static and the dynamic methods, the first crack appears as a circle. See Figs. 240 and 241 wherein there is an increasing amount of energy thrown into the impact in the successive pictures. The manner of the breaking of glass when struck by a steel ball or a bullet is familiar to all who have seen the glass in a windshield struck by a flying stone or any other missile. The break is always of the same character and after such a break the direction of the impact is always ascertainable. Fig. 242 shows the characteristic form of a break in glass when struck by a spherical missile.



Courtesy H. O'Neill

Fig. 238. O'Neill's Ball Sclerometer leaves a smooth trace as it crosses: (a) a block of large crystals of iron and (b) the boundary between two strained crystals.

THE PHENOMENON OF CREEP AND ITS RELATION TO HARDNESS MEASUREMENTS

Definition of Creep.—In studying the elastic properties of metals at room temperature (see Nov. 1938 instrument) there is a fairly constant ratio between the stress applied and the strain produced within the so-called elastic limits. If a tension is applied to a steel rod and an elastic deformation occurs, the strain thus set up comes to a fixed amount immediately, and no matter how long the load is applied the deformation remains constant so far as can be observed by ordinary means. Thus in Fig. 243 the line *O A B* would represent this physical process in which *O A* is the immediate deformation when the load is applied and continues uniformly at that value along the dotted line *AB* so long as the stress is applied.

If, however, the temperature of the steel is raised an increase in the immediate deformation occurs which is now *OC* instead of *O A* when the same load is applied.

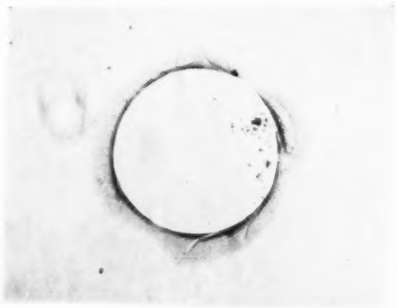


Fig. 239. The first break is a hairlike ring in the glass. As shown by the shadow around the ring the break has already extended some distance into the glass.

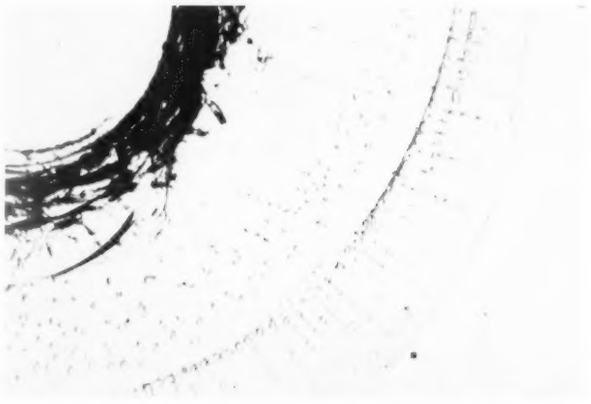


Fig. 240. Here the break has extended still farther into the glass than in the break in Fig. 239. The little oval drops are minute particles of water drawn into the crack.

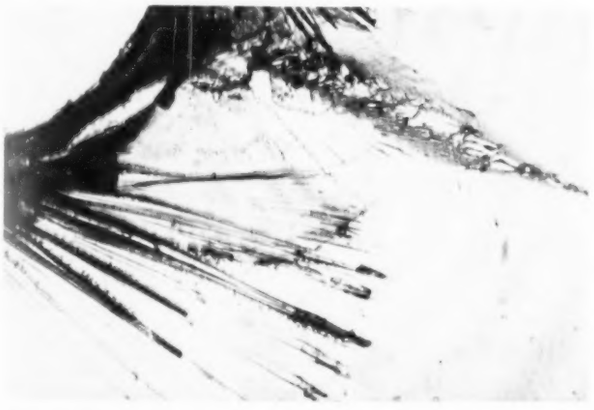


Fig. 241. The circular break in the surface of the glass has progressed so far that the edges of the initial circular break have been seriously shattered.

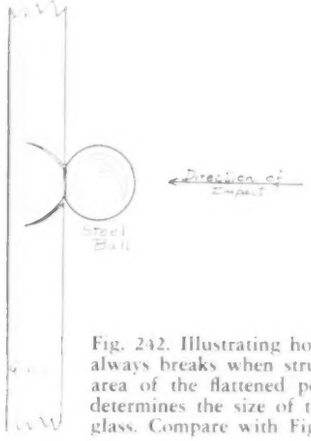


Fig. 242. Illustrating how a piece of plate glass always breaks when struck by a projectile. The area of the flattened portion of the steel ball determines the size of the circular crack in the glass. Compare with Fig. 170.

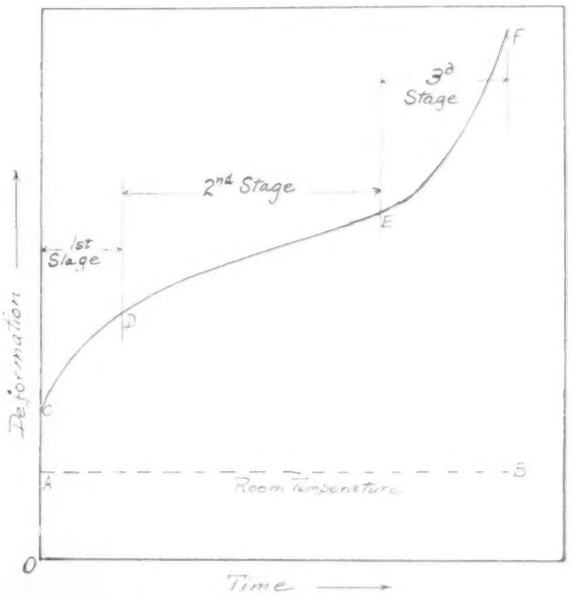


Fig. 243. Illustrating the deformations which go on as time progresses.

A part of the initial deformation at the higher temperature is due to a plastic yielding. In addition to the increase of the initial deformation at higher temperatures it keeps on increasing with the time and follows a curve similar to *CDEF* in Fig. 243, which is thought of as being divided into three stages as indicated.

Following a discussion by Clark and White[6] creep may be defined as that deformation which goes on with time although the stress (load) remains constant. It is that deformation in Fig. 243 represented by the curve *CDEF*.

[6] C. L. Clark and A. E. White, Creep Characteristics of Metals. *Transactions American Society for Metals*, Vol. 24, 1936, pages 831-869. (30-page preprint.)

In the study of hardness thus far, emphasis has been placed on the idea that such a study cannot be based on metals alone. Hardness must be defined in terms of all kinds of solid matter. The same holds true for the creep phenomena and when this guiding principle is followed it leads to highly interesting results and in particular as to what one observes when an indenter is pushed into the surfaces of various materials, especially those in which creep occurs at room temperature. For instance, when the regular "B" scale is used on the Rockwell tester and a test is made on mild steel, almost immediately the dial indicator registers a definite read

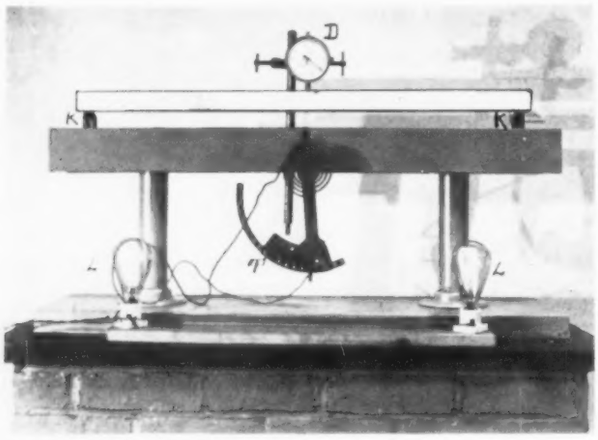


Fig. 244. A bar of marble is laid on two knife edges at *K* and *K*. Due to its own weight the bar begins to sag (creep) at the middle and the amount is indicated by the dial indicator *D*. *T* is the thermostat control for the heating lamps *L* and *L*.

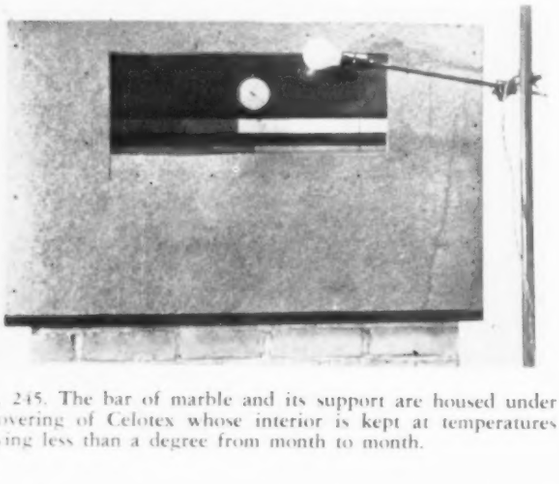


Fig. 245. The bar of marble and its support are housed under a covering of Celotex whose interior is kept at temperatures varying less than a degree from month to month.

ing which may be represented by the line *OA* in Fig. 243. This is not the case when the same test is applied to a piece of plastic like methyl methacrylate: the ball keeps on creeping into the surface as time goes on and goes through stages similar to those in *CDEF*, Fig. 243. A study of creep in substances at ordinary room temperatures is therefore of great interest to one who is studying hardness and its measurement.

One of the physical processes observed in the measurement of hardness in plastics, therefore, is the phenomenon of creep and where creep occurs in ordinary hardness testing the question naturally arises, What is its hardness, today or tomorrow? It is evident that with creep present the reading on a dial indicator of a Rockwell machine will show a much softer reading tomorrow than it will today, if the load is left on until the creep has subsided.

Some study has been made on a series of plastics like Bakelite, Lucite and others in which the scale of the Rockwell tester has been used. Consistent readings may be obtained in this manner with the "L" scale; first the preliminary load is applied and then the final load which is left on for 30 seconds and most of the creep has subsided. At this point the major load is removed and again a wait of 30 seconds is made before the final Rockwell number reading is made. This slows up the speed with which one may make the tests, but they appear reliable. It is fortunate in studying plastics that a large part of the creep effect is over by the end of each one of the 30-second periods. Whether the creep is over or not, this furnishes us a procedure for comparing the hardness numbers of various plastics or other substances which

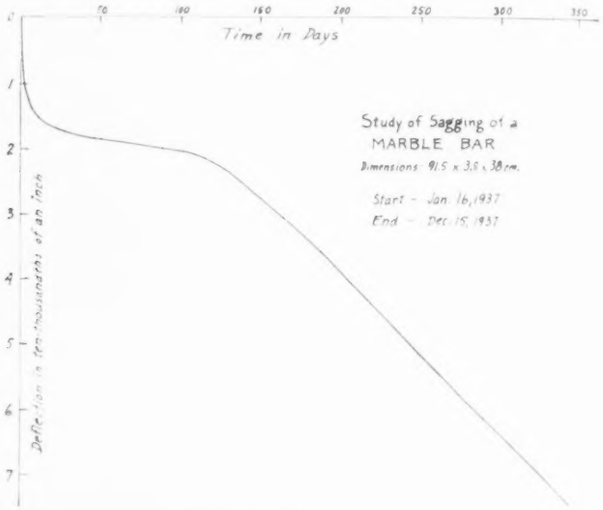


Fig. 246. Creep effect in marble.

show creep, because a time factor has been introduced into the readings of sufficient length so that one can duplicate it with some accuracy. This period of time for waiting may be arbitrarily set to any desired interval. Although time-consuming, it is better to wait until most of the creep effect has disappeared.

In the thought that a study of the phenomenon of creep might throw some light on hardness testing and on what goes on under the impress of the indenter of a hardness tester, creep tests have been inaugurated on substances like marble, glass and Lucite. The experiments on marble have been going for two years and those for glass and Lucite are now well under way.

The creep effect in marble is so large that if a square rod 91.5 cm. long and 3.8 cm. on a side is laid on knife edges *K* and *K*, as shown in Fig. 244, one can see the hand on the dial indicator move steadily forward in the first half hour of creep due to the stress which is its own mass.

Fig. 245 shows how the bar of marble and its entire support were inclosed in a housing of Celotex with a glass window in the front. By means of the thermostat *T*, shown in Fig. 244, the temperature was maintained constant within a small fraction of one degree. The turning off and on of the heat from the two lamps *L L* by the thermostat was sufficient to maintain a constant temperature.

In Fig. 246 is shown the progress of the creep (sagging) of the middle of the marble bar as time progressed

When this curve is shown in greater detail than in Fig. 246 it will be seen to be composed of steps which in themselves have the form of the first stage of a creep curve. These steps almost appear as periodic events, so regularly do they occur. This is shown in Fig. 247. The creep-time curve shown in Fig. 246 has been going on now for over two years. It continued to creep regularly for a year and a half and then ceased altogether for a half year. After this lapse of a half year the creep in the marble rod is continuing again, at the time of writing, and in progressive jumps as in Fig. 247.

In the Rock Creek Cemetery, Washington, D. C., is a famous tombstone which consists of a flat slab of marble supported at its four corners. During the years this slab has existed as a memorial the process of creep has been going on and today, although not broken, the center has sunk several inches.[7] In some places marble

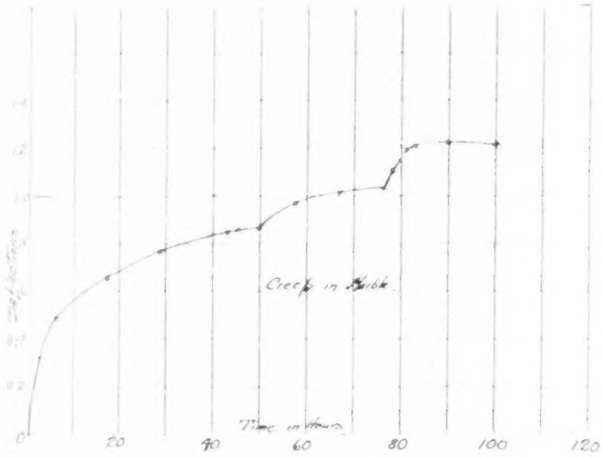


Fig. 247. Detailed study of the creep effect in marble.

has been used for lintels to doorways and openings for windows. Unless supported by steel they will almost invariably be found to have sagged due to the creep phenomenon.

In the process of creep, as thus studied in marble, just what is happening? Marble is made up of many small crystals or grains whose surfaces slip (creep) past one another, gradually allowing the marble bar to sag. The free spaces between the grains vary in different marbles and by the amount of water absorbed it can be determined what intercrystallite space exists in the marble.

In Fig. 247 it would appear that there is a gradual slipping of one crystal surface or plane over the other until it finally catches and holds steady for awhile. The picture of creep in Fig. 247 is much like that described by Jeffries and Archer[8] in their slip interference theory of the hardening of metals. After the creep slows up due to a slip interference at some boundary plane, a sudden mechanical jar, change in temperature or any imposed stress will start some other set of planes to creeping over each other and thus we obtain a series of steps as shown in Fig. 247. As indicated above, where the stress is constant these steps come along with almost periodic regularity.

Such a picture of the phenomenon of creep leads to a comment on the periodic fluctuations of hardness with time which the late E. G. Herbert[9] observed some years ago. Herbert found that if a piece of steel wire was quenched from about 780° C., the steel would go through a cyclic process on age hardening. One of Herbert's curves is shown in Fig. 248. He found that not only heat, but magnetic and mechanical stresses set up these cyclic-processes during the hours following the application of the various types of stresses.

Why should these variations appear cyclic? Herbert set up the hypothesis that the precession of the electrons in the atoms causes cycle fluctuations in molecular cohesion and thus varies the hardness in a cyclic fashion. This picture of what is happening in the fluctuations of hardness as time progresses seems difficult to understand. The phenomenon of creep in the bar of marble, however, sheds some light on Herbert's discovery of cyclic fluctuations in hardness. It would seem probable

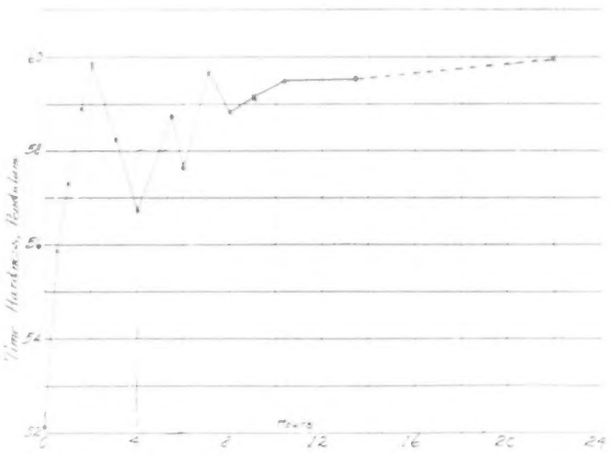


Fig. 248. Fluctuations of hardness in steel wire during aging after quenching.

that one either sets up a strain in a medium or releases it by magnetic, heat or mechanical processes. When these strains are set up or released a common result occurs for all, slippage occurs or creep sets in along the crystal surfaces. In the case of the marble bar, its own weight forms the stress which sets up strains in the marble and by a process of slippage at the grain boundaries it releases these strains by steps which appeared cyclic as shown in Fig. 247.

Such processes go on in metals as Herbert found. Strains always seem to be present in solids and, as they release themselves, creep occurs. The presence of such strains was recently demonstrated in sawing slowly and carefully a piece of brass tubing lengthwise. After the cut had been carried about 15 cm. along the tube it was found that certain strains had been released and each half of the tube was twisted to one side from the other half. Yet this brass tube had been in the stock room at least 25 years. The strains were mechanically released and could they have been observed as the saw progressed it would doubtless have been found that the release had been a pseudo-cyclic or step-by-step release.

Another indication of this strain always being present in solids is the fact that it is extremely difficult to find a piece of glass free from strains when viewed by polarized light. *(To be Continued)*

[7] R. N. Traxler. Everything Flows. *Scientific American*, Vol. 160, 1938, pages 16-18.

[8] Z. Jeffries & R. S. Arther. The Slip Interference Theory of the Hardening of Metals. *Chemical & Metallurgical Engineering*, Vol. 24, 1921, pages 1057-1067.

[9] E. G. Herbert. Improving the Quality of Tool Steel by Magnetic Treatment. *Metallurgia*, Vol. 9, Nov. 1933, pages 11-15. (6-page reprint) E. G. Herbert. A Low Thermal Stress Heat Treatment. *Metallurgia*, Vol. 10, Sept. 1934, pp. 153-154 (2-page reprint).
See also—C. W. Briggs. Aging Fluctuations of Brinell Hardness. *Transactions American Society for Steel Treating*, Vol. 21, 1933, pages 424-434.

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EDITORIAL COMMENT

(Continued from page 63)

control of chemical composition. From this province we arbitrarily exclude a number of useful portable analyzers—deservedly called "industrial"—which require manipulation or which are not capable of providing pointer-and-scale indications or chart records, and limit our discussions to *automatized* chemical analysis.

Two distinct historical sequences have resulted in automatic analyzers. One has been the gradual evolution of fragile laboratory bench glassware into rugged apparatus, with more and more routine operations mechanized, from the taking of uniform samples at the start to the taking of readings at the end. This form of automatization is the mechanization or motorization of previously manual or visual routines. The other historical sequences has been more rapid in every case: not an evolution but the application of continuously-recording instruments to continuous methods—or the transformation of a laboratory continuous analysis apparatus into a fully-automatic continuous analysis industrial instrument. The term "analyzer" generally signifies a selective analyzer—an instrument which records one constituent by one selective method, or a duplex or multiplex recorder consisting of two or more fundamental measuring devices assembled into one case so as to produce a plurality of records on a single chart. Though new, this province of automatized analysis comprises a number of fields, more or less overlapping and only faintly corresponding to the formal divisions in college chemistry courses. We discern ten distinct fields in this province—ten "classes" of robotized analyzers:

(I) Automatized gas analysis methods in which the percentage of a constituent is measured by measuring a physical property of the mixture, without any chemical reaction being performed. Any physical property may be utilized which is readily measurable or—better still—continuously measurable by an industrial instrument. It must be noted, of course, that the mixture rule limits the application of property-measurement methods to mixtures where the value of the utilized property is appreciably greater or smaller in the gas to be recorded than in any other constituent. Another peculiarity in the use of property-measuring methods of gas analysis is that the different constituents frequently have different temperature or pressure coefficients of the particular property. This may be a source of error but it also permits analyzing certain mixtures at temperature where the constituent tested for displays the utilized property more markedly than do the other constituents. Finally, most of these methods being continuous in their industrial embodiments, the instruments can readily be made to serve as the measuring elements of telemetering systems, or of automatic control systems.

(II) Same as (I) but for solutions. Among the physical properties reliably indicative of the concentration of a particular ion, element or compound in a solution, the most useful are electrical properties. These come under electrometric methods which for reasons of convenience constitute a field of their own. (No. VIII, below). Any of the remaining physical properties can be utilized when it can conveniently and accurately be recorded, when the ion, element or compound tested for has a pronounced influence on the value of the solution's property and when there is practically no danger of the presence of other ions, elements or compounds affecting the shape of the curve on which the instrument's calibration is based.

(III) Mechanized volumetric gas analysis methods consisting of a single selective absorption or selective oxidation stage for quantitative determination of one constituent of the mixture, preceded and followed by simple automatized washings and other routines. Modern features are designed to assure definite conditions of pressure, volume, temperature and either drying or saturation; or to compensate automatically for variations in some of these con-

tions. In large plants the readings obtained from the final nometer bell of the analyzing instrument are converted to proportional electrical effects and telemetered to centralized control boards at a distance from the points of nalysis. Any of these indicating and recording instruments, moreover, can readily be made to serve as the measuring element of an intermittent type automatic control system which, after each cycle of measurement, readjusts various valves and dampers.

(IV) Mechanized volumetric methods similar to (III) but comprising two or more selective absorption or oxidation stages—either because the determination of one constituent requires it or in order to measure the percentages of a plurality of gases.

(V) Continuous-absorption gas analyzers with pressure-measuring instruments serving as indicators, recorders and telemetering-system transmitters. Since measurement is continuous, the instruments can be supplemented by a wide choice of telemetering or automatic-control systems.

(VI) Combination of chemical reaction and physical property measurement.

(VII) Inferential analysis by measurements of effects of changes of forms of energy accompanying reactions. Though generalized by the plural, this obviously refers chiefly to temperature measurements in connection with strong exotherms or endotherms. Outstanding example is the catalysis-cell type of CO recorder.

(VIII) Electrometric methods of analysis. This field necessarily overlaps others. By usage it includes methods based on the *electrical* conductivity of solutions, but it excludes methods based on the *thermal* conductivity of gases —the former being considered an electrochemical property and the latter a purely physical property. Important as is this field, it has not yet been defined. The electrometric analytical methods which are successfully embodied in industrial instruments, however, may be listed* as follows: (1) potentiometric, (2) electrolytic, (3) polammetric, (4) conductivimetric, (5) magnetometric.

(IX) Qualitative detection of any or all unknowns. This has not yet reached the practical stage, though a certain measure of success has been reported in the way of spectroscopes equipped with photocells and sets of screens, each screen having a series of slits corresponding to the principal bands or lines of a certain atom or molecule.†

(X) General quantitative analysis. Complete automatization still is in the dream stage for it would seem to require (even if limited to the inorganic field) an enormous apparatus corresponding to a large laboratory in which all manipulations are automatized (including judicious choice of reagents for obvious reasons such as explosion prevention) and provided either with a multitude of dials or with means of printing on a chart the result in the form of symbols and quantities. By the way, how many laboratories (staffed by human chemists, not robots) are today capable of reporting exactly (say to 1% of each amount) all amounts of all constituents in any material?

V—Return Flights

There is an equally fascinating subject: Modern laboratory instruments which are modifications of types developed for the plant . . . or which are taken over from the plant without modification. To be sure, an industrial instrument without any immigrant ancestors (that came over from the laboratory) is rather difficult to imagine, but this circularity makes the subject all the more interesting. One example at random: the autographic and integrating accessories of a large-scale apparatus for pure research, recently pictured in Sunday newspapers.—MFB

*To spare the weary reader we omit our definitions and discussions of the five "types" of industrial electrometric instruments. They will be published anyway—before 1950!

†In the June 1928 issue of *Instruments* Arthur Schroder disclosed in detail his conception of an "Automatic Spectrum Analyzer" designed to be sighted on the flaming discharge from a Bessemer converter and to sound a bell the moment CO_2 appears, which change marks the end-point of the reaction.

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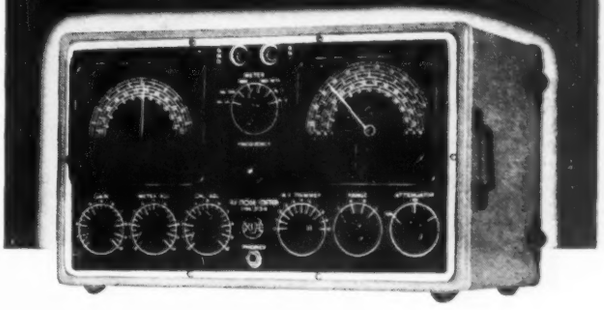

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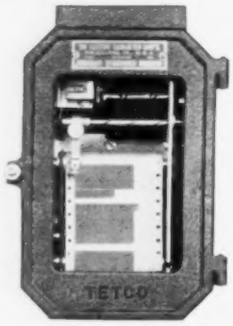

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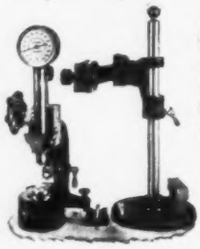

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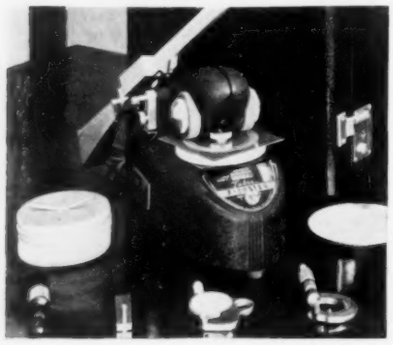

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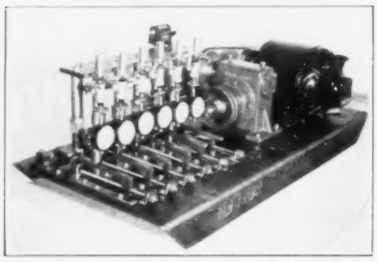

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